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# **Perkins 2800 Series**

Models 2806C-E18 TAG1 TAG2 and TAG3

## **WORKSHOP MANUAL**

**6 cylinder turbocharged diesel engines for industrial,  
applications**

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# 1

## General information

### Introduction

The 2800 Series engines are from Perkins Engines Company Limited, a world leader in the design and manufacture of high-performance diesel engines.

Perkins approved assembly and quality standards, together with the latest technology, have been applied to the manufacture of your engine to give you reliable and economic power.

This Workshop Manual has been designed to provide assistance in the service and the overhaul of Perkins 2806 C 18 engines. Most of the general information, which is included in the User's Handbook (Chapters 1 to 6), has not been repeated in this Workshop Manual and the two publications should be used together.

To ensure that you use the relevant information for your specific engine type, refer to "Engine identification" on page 6.

When reference is made to the "left" or "right" side of the engine, this is as seen from the flywheel end of the engine.

Special tools have been made available and a list of these is given in Chapter 16, Special tools. Reference to the relevant special tools is also made at the beginning of each operation.

Data and dimensions are included in Chapter 2, Specifications.

Read the "Safety precautions" on page 2 and remember them. They are given for your protection and must be applied at all times.

In addition to the general safety precautions, danger to both operator and engine are highlighted by the following conventions:

**Warning!** *This indicates that there is a possible danger to the person (or the person and engine).*

**Caution:** *This indicates that there is a possible danger to the engine.*

**Note:** Is used where the information is important, but there is not a danger.

## Safety precautions

These safety precautions are important. You must refer also to the local regulations in the country of use. Some items only apply to specific applications.

- Always refer to the text of this handbook for specific warnings and cautions.
- Only use these engines in the type of application for which they have been designed.
- Do not change the specification of the engine.
- Do not make adjustments that you do not understand.
- Do not allow the engine to stand on its sump.
- Do not smoke when you put fuel in the tank.
- Clean away fuel which has been spilt. Material which has been contaminated by fuel must be moved to a safe place.
- Do not put fuel in the tank while the engine runs (unless it is absolutely necessary).
- Do not clean, add lubricating oil, or adjust the engine while it runs (unless you have had the correct training; even then extreme caution must be used to prevent injury).
- Ensure that the engine does not run in a location where it can cause a concentration of toxic emissions.
- Other persons must be kept at a safe distance while the engine or auxiliary equipment is in operation.
- Do not permit loose clothing or long hair near moving parts.

**Warning!** *Keep away from moving parts during engine operation. Some moving parts cannot be seen clearly while the engine runs.*

- Do not operate the engine if a safety guard has been removed.
- Do not remove the filler cap or any component of the coolant system while the engine is hot and while the coolant is under pressure, because dangerous hot coolant can be discharged.
- Do not allow sparks or fire near the batteries (especially when the batteries are on charge) because the gases from the electrolyte are highly flammable. The battery fluid is dangerous to the skin and especially to the eyes.
- Disconnect the battery terminals before a repair is made to the electrical system. Always disconnect the negative terminal first.
- Only one person must control the engine.
- Ensure that the engine is operated only from the control panel or from the operator's position.
- If your skin comes into contact with high-pressure fuel, obtain medical assistance immediately.
- Diesel fuel and lubricating oil (especially used lubricating oil) can damage the skin of certain persons. Protect your hands with gloves or a special solution to protect the skin.
- Do not wear clothing which is contaminated by lubricating oil. Do not put material which is contaminated with oil into the pockets.
- Discard used lubricating oil and coolant in accordance with local regulations to prevent contamination.
- The combustible material of some components of the engine (for example certain seals) can become extremely dangerous if it is burned. Never allow this burnt material to come into contact with the skin or with the eyes.

*Continued*

- Always use a safety cage to protect the operator when a component is to be pressure tested in a container of water. Fit safety wires to secure the plugs which seal the hose connections of a component which is to be pressure tested.
- Do not allow compressed air to contact your skin. If compressed air enters your skin, obtain medical help immediately.
- Turbochargers operate at high speed and at high temperatures. Keep fingers, tools and debris away from the inlet and outlet ports of the turbocharger and prevent contact with hot surfaces.
- Some components are not waterproof and should not be washed with a high-pressure water jet or steam.
- Fit only genuine Perkins parts.

## Viton seals

Some seals used in engines and in components fitted to engines are made from Viton (fluorocarbon).

Viton is used by many manufacturers and is a safe material under normal conditions of operation.

If Viton is burned, a product of this burnt material is an acid which is extremely dangerous. Never allow this burnt material to come into contact with the skin or with the eyes.

If it is necessary to come into contact with components which have been burnt, ensure that the precautions which follow are used:

- Ensure that the components have cooled.
- Use Neoprene gloves and discard the gloves safely after use.
- Wash the area with a calcium hydroxide solution and then with clean water.
- Disposal of gloves and components which are contaminated, must be in accordance with local regulations.

If there is contamination of the skin or eyes, wash the affected area with a continuous supply of clean water or with a calcium hydroxide solution for 15-60 minutes. Obtain immediate medical attention.

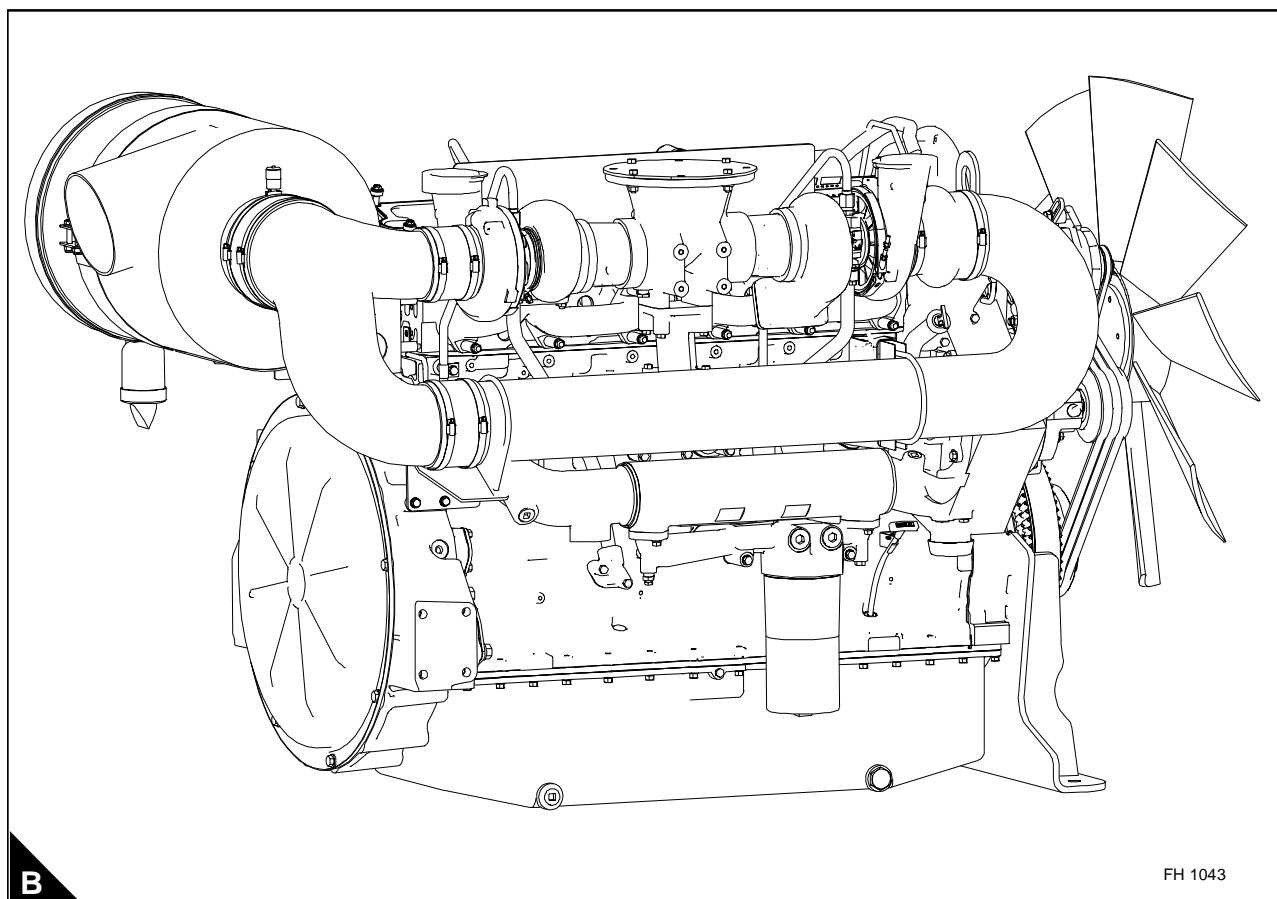
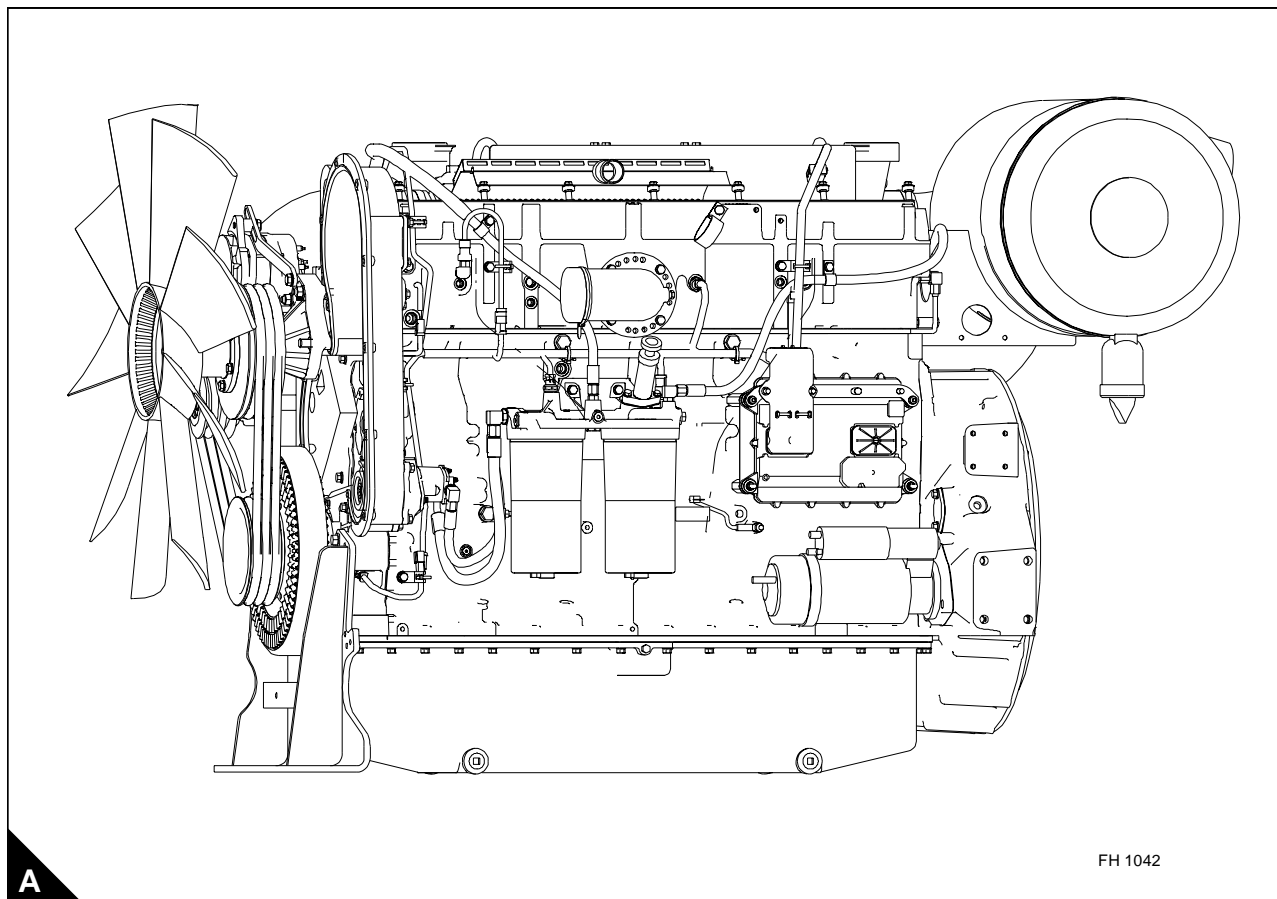
## Welding

Welding can cause damage to the electronic components fitted to the engine. If welding is necessary, the precautions which follow must be undertaken before and during the welding operation.

### **Cautions:**

- *Switch off the engine.*
- *Disconnect the cable from the negative terminal of the battery. If the machine is fitted with a battery disconnect switch, then open the switch.*
- *If welding to the engine, remove the ECM (electronic control module).*
- *If welding onto the machine chassis, ensure that the earth clamp is attached as close to the welding point as possible and NOT near to the ECM.*
- *If it is necessary to weld near to the ECM, remove the ECM from the engine.*

## Engine views



## Engine identification

If you need parts, service or information for your engine, you must give the complete engine number. The engine number is stamped on a data plate which is fastened to the right side of the engine.

A typical engine number is: HGA060125U 1103H, which consists of these codes:

<b>G</b>	Code for engine capacity
<b>G</b>	Engine application
<b>A</b>	Engine type
<b>06</b>	Number of engine cylinders
<b>0125</b>	Engine specification number
<b>U</b>	The country of manufacture
<b>1103</b>	Build line number
<b>H</b>	Year of manufacture

## Engine lift equipment

The total dry weighs is approximately 2050 kg (4516.4 lb). Ensure that the lift equipment used is suitable. An adjustable lifting beam should be used and the chains or cables must be parallel to each other during use.

Before the engine is lifted:

- Always use lift equipment of the approved type and of the correct capacity to lift the engine. Never use a single lift bracket to raise an engine.
- Check the engine lift brackets for damage and security before the engine is lifted.

Use suitable lift equipment or obtain assistance to lift heavy engine components such as the cylinder block, cylinder head, damper unit, flywheel housing, crankshaft and flywheel.

**Warning!** *The lifting eyes which are fitted to the engine must be used for lifting only the engine. Do NOT use them to lift the engine if it is still attached to its driven unit.*



# 2

## Specifications

### Basic engine data

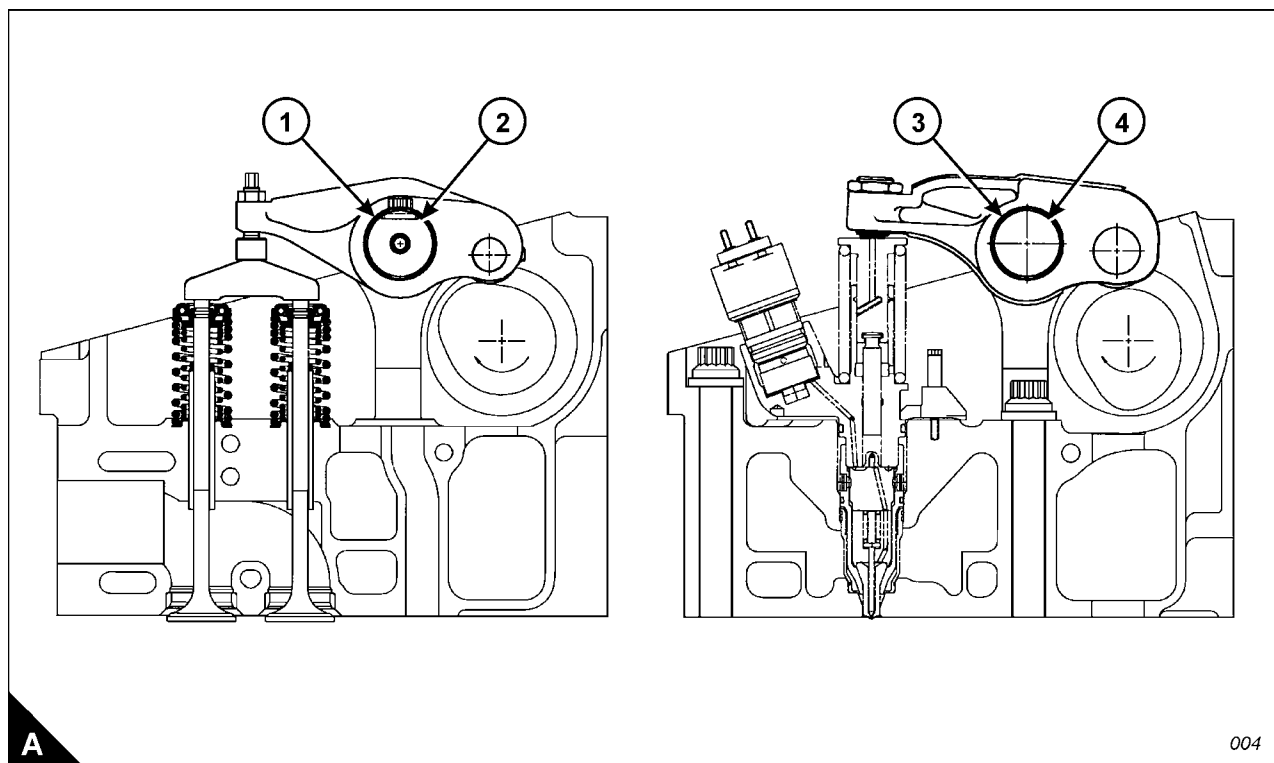
Number of cylinders. ....	6
Cylinder arrangement.. ....	In line
Cycle .....	Four stroke
Induction system.. ....	Air to air charged cooled
Combustion system. ....	Direct injection
Nominal bore .....	145 mm (5.708 in)
Nominal stroke. ....	183 mm (7.204 in)
Compression ratio .....	14.5:1
Cubic capacity .....	18,13 litres (1106.36 in <sup>3</sup> )
Firing order .....	1, 5, 3, 6, 2, 4
Direction of rotation .....	Anti-clockwise viewed on flywheel
Lubricating oil capacity:	
Total system .....	55,5 litres (97.6 UK pints)
Sump maximum... ..	53,5 litres (94.14 UK pints)
Sump minimum .....	37,5 litres (65.99 UK pints)
Lubricating oil pressure:	
At rated speed .....	4,2 bar (60.9 PSI)
Typical coolant capacity of engine... ..	20,8 litres (4.6 UK gallons)
Typical coolant capacity of engine and radiator .....	61 litres (13.4 UK gallons)

## Rocker assemblies

Rocker shaft diameter (A2) .....	40,000 +/- 0,010 mm (1.5748 +/- 0.0004 in)
Valve rocker lever bore (A1) .....	40,065 +/- 0,015 mm (1.5774 +/- 0.0006 in)
Bearing clearance between valve rocker lever and shaft .....	0,040 to 0,090 mm (0.0016 to 0.0035 in)
Unit injector rocker lever bore (A3) .....	43,000 +/- 0,020 mm (1.6929 +/- 0.0008 in)

If a new bearing is fitted to the unit injector rocker lever, the oil hole in the bearing must be aligned with the oil passage in the rocker lever within 2,4 mm (0.09 in). The bearing must not extend beyond either face of the rocker lever.

Bore in the rocker lever bearing (A4) . ....	40,065 +/- 0,15 mm (1.5774 +/- 0.0006 in)
Maximum permissible worn dimension .....	40,193 (1.5824 in)



A

004

**Valves**

Diameter of valve stem (A1) ... 9,441 +/- 0,010 mm (0.3717 +/- 0.0004 in)

Permissible worn dimension ... 9,309 mm (0.3665 in)

Diameter of valve head (A3):

Inlet valve ... 47,00 +/- 0,13 mm (1.850 +/- 0.005 in)

Exhaust valve ... 41,81 +/- 0,13 mm (1.646 +/- 0.005 in)

Angle of face of valve (A2):

Inlet valve ... 29 1/4 +/- 1/4 degrees

Exhaust valve ... 44 1/4 +/- 1/4 degrees

Minimum thickness of valve lip (A4):

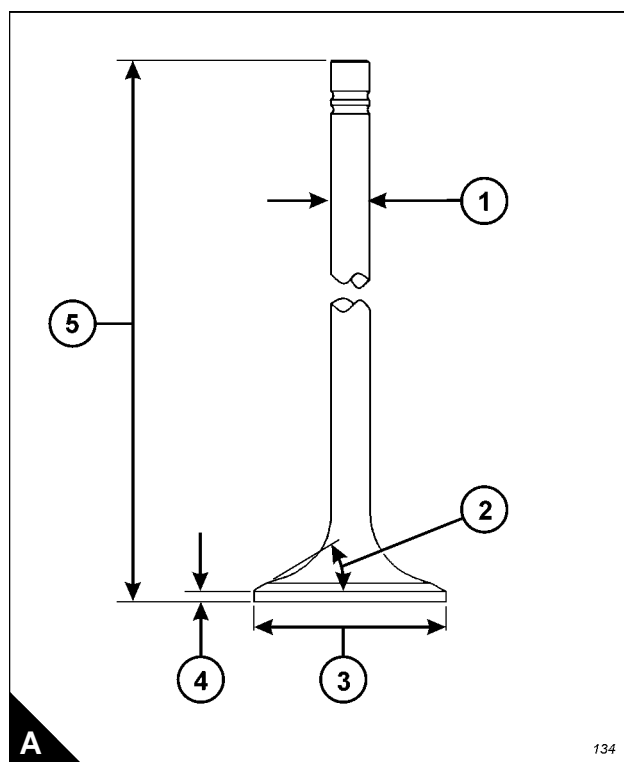
Inlet valve ... 2,75 mm (0.108 in)

Exhaust valve ... 2,05 mm (0.081 in)

Length of valve:

Inlet ... 202,00 +/- 0,45 mm (7.953 +/- 0.018 in)

Exhaust ... 202,06 +/- 0,45 mm (7.955 +/- 0.018 in)



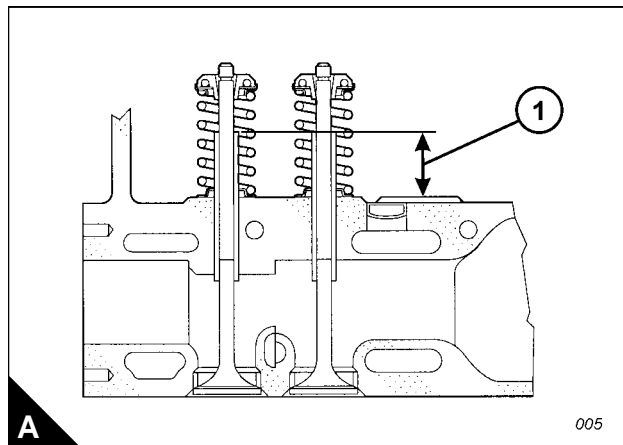
## Valve guides

Bore of valve guide when installed ... .. 9,484 +/- 0,026 mm (0.3734 +/- 0.010 in)

Maximum permissible dimension... .. 9,538 mm (0.3755 in)

Do not use a combination of a valve and valve guide which have a difference of 0,13 mm (0.005 in) or more.

Height from cylinder head to top of valve guide (A1) . ... .. 35,00 +/- 0,50 mm (1.378 +/- 0.020 in)



## Valve springs

### Inner

Assembled length .. ... 60,14 mm (2.368 in)

Load at assembled length.. ... 150 +/- 12 N (34 +/- 3 lb)

Minimum operating length.. ... 44,02 mm (1.733 in)

Load at minimum operating length. ... 400 +/- 20 N (90 +/- 4 lb)

Free length after test.. ... 71,7 mm (2.823 in)

Outside diameter ... .. 25,17 mm (0.991 in)

### Outer

Assembled length .. ... 67,12 mm (2.643 in)

Load at assembled length.. ... 320 +/- 25 N (72 +/- 6 lb)

Minimum operating length.. ... 51,00 mm (2.008 in)

Load at minimum operating length. ... 900 +/- 45 N (202 +/- 10 lb)

Free length after test.. ... 76,7 mm (3.02 in)

Outside diameter ... .. 36,30 mm (1.429 in)

## Valve seat inserts

Depth of bore in cylinder head for valve seat insert (A5):

Inlet valve ... 14,00 +/- 0,10 mm (0.551 +/- 0.004 in)

Exhaust valve ... 13,90 +/- 0,10 mm (0.547 +/- 0.004 in)

Diameter of valve seat insert (A2):

Inlet valve ... 48,025 +/- 0,13 mm (1.8907 +/- 0.0005 in)

Exhaust valve ... 42,840 +/- 0,13 mm (1.6866 +/- 0.0005 in)

Bore in cylinder head for valve seat insert (A2):

Inlet valve ... 47,950 +/- 0,025 mm (1.8878 +/- 0.0010 in)

Exhaust valve ... 42,774 +/- 0,025 mm (1.6840 +/- 0.0010 in)

Angle of face of valve seat insert (A1):

Inlet valve insert... 30 1/4 +/- 1/2 degrees

Exhaust valve insert ... 45 1/4 +/- 1/2 degrees

Valve recess (A4):

Inlet valve (new parts) ... 2,20 to 2,80 mm (0.087 to 0.110 in)

Exhaust valve (new parts) ... 1,20 to 1,80 mm (0.047 to 0.071 in)

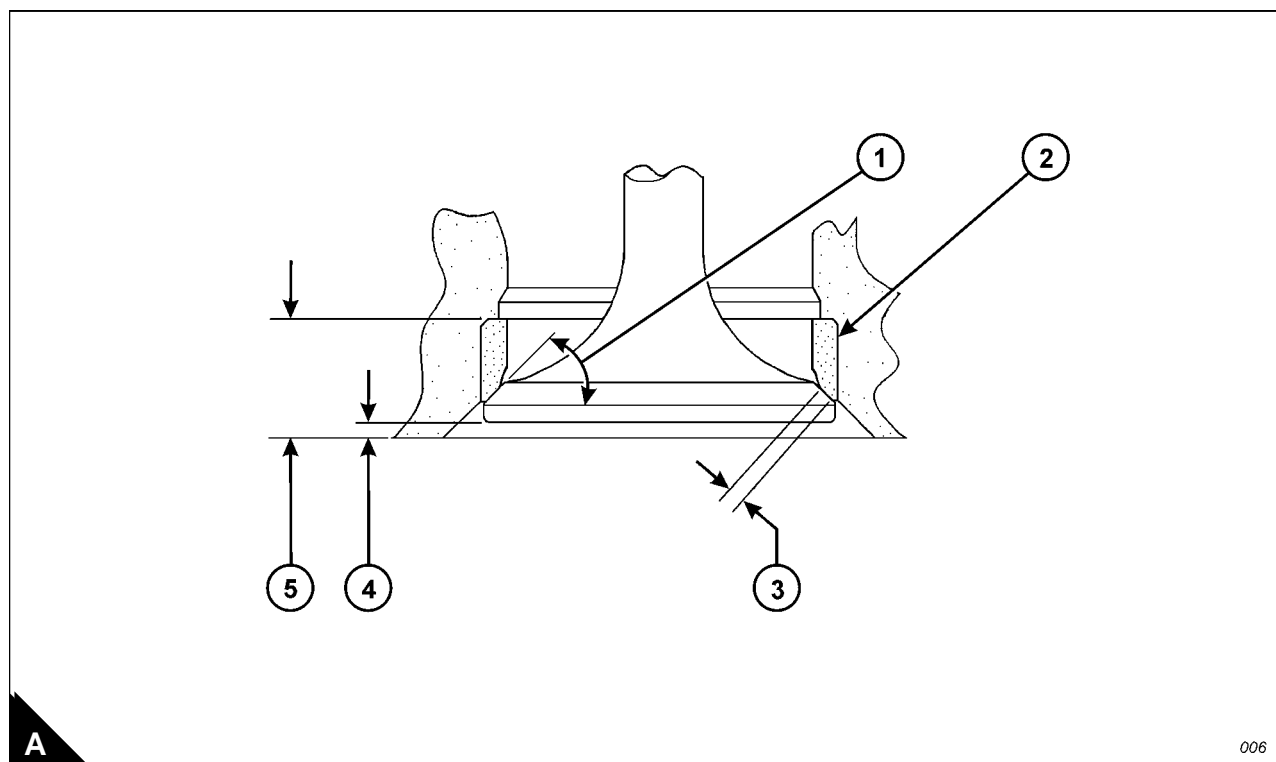
Inlet valve (reconditioned parts) ... 2,20 to 3,29 mm (0.087 to 0.129 in)

Exhaust valve (reconditioned parts) ... 1,20 to 2,29 mm (0.047 to 0.090 in)

Minimum recommended width of valve seat (A3):

Inlet... 2,334 mm (0.079 in)

Exhaust ... 1,507 mm (0.049 in)



## Cylinder head

Thickness of cylinder head (new) .. ... 120,00 +/- 0,15 mm (4.724 +/- 0.006 in)

Minimum thickness for a used cylinder head. .... 119,50 mm (4.705 in)

**Flatness of cylinder head:** The cylinder head must be flat to within a total of 0,13 mm (0.005 in). Additionally, the cylinder head must be flat within a maximum of 0,03 mm (0.001 in) across any 76,2 mm (3.00 in) span.

## Camshaft and bearings

Diameter of camshaft journal (A3) . ... 84,85 +/- 0,02 mm (3.341 +/- 0.001 in)

Exhaust lobe lift.. ... 8,515 mm (0.3352 in)

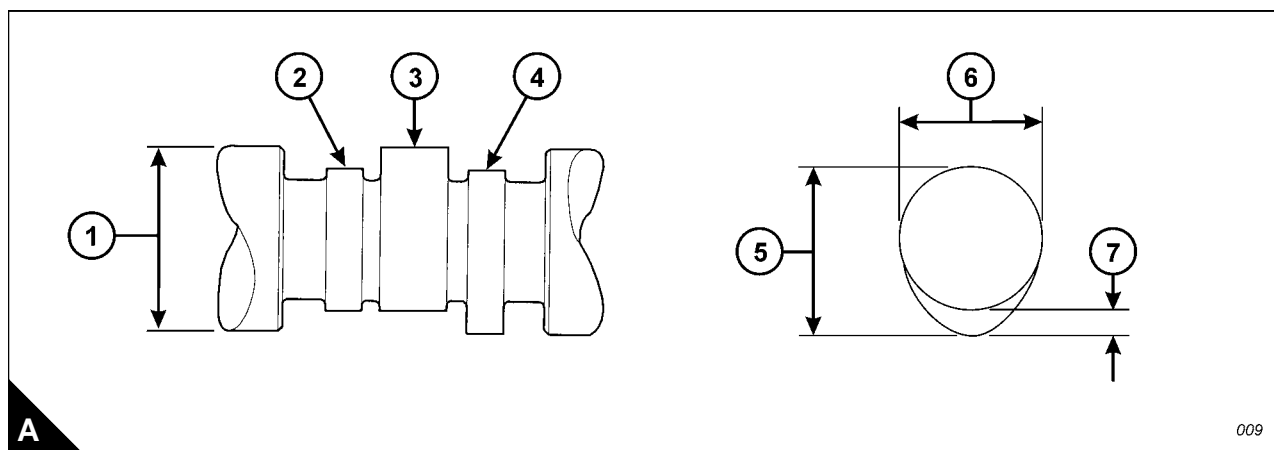
Inlet lobe lift ... 9,702 mm (0.382 in)

Injector lobe lift... 10,451 mm (0.4114 in)

Maximum permissible difference between the actual lobe lift (E7)

and the specified dimension .. ... 0,100 mm (0.0039 in)

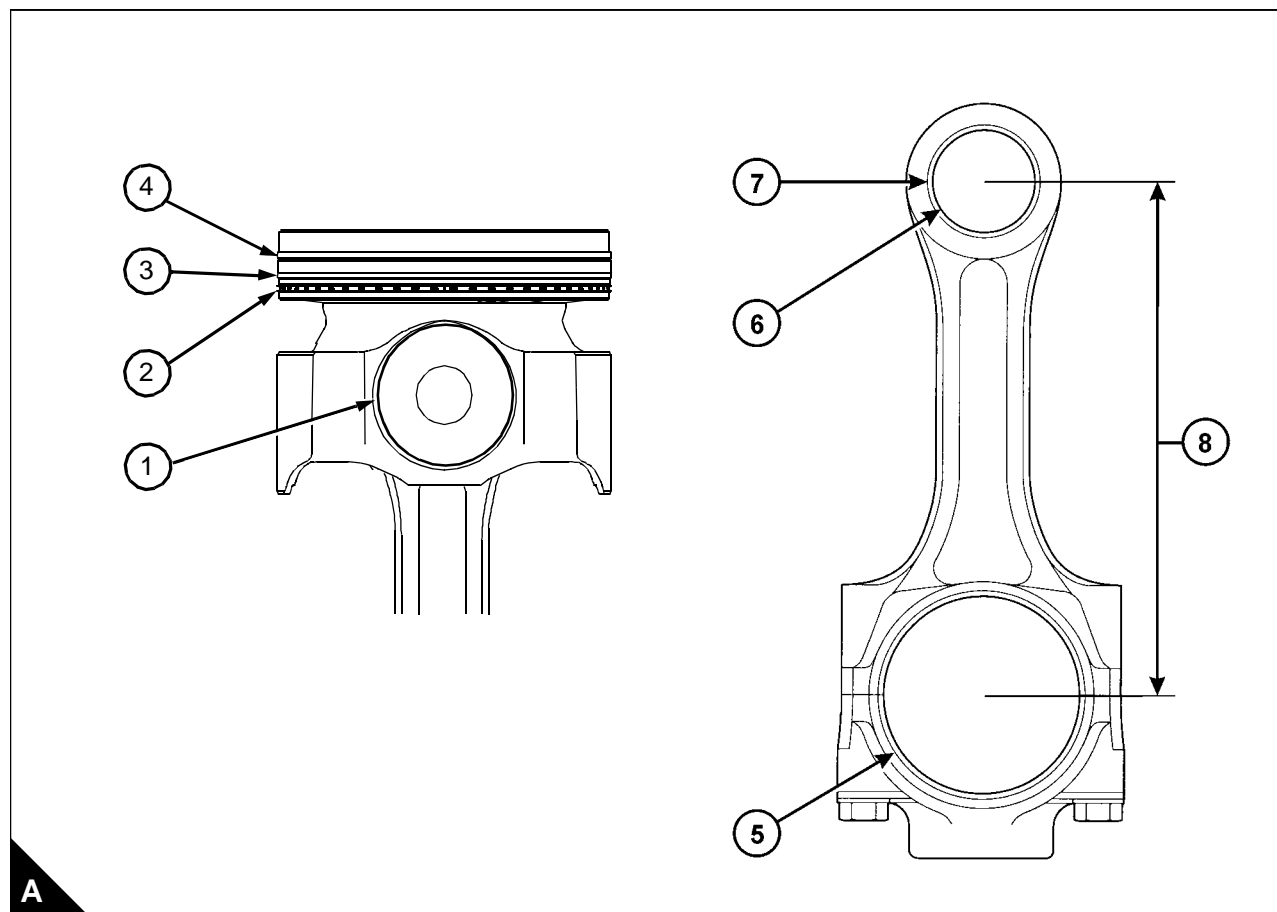
To obtain the lobe lift (A7) proceed as follows: Measure the lobe height (A5) and measure the base circle (A6). Subtract the base circle from the lobe height to give the lobe lift.



## Pistons and connecting rods

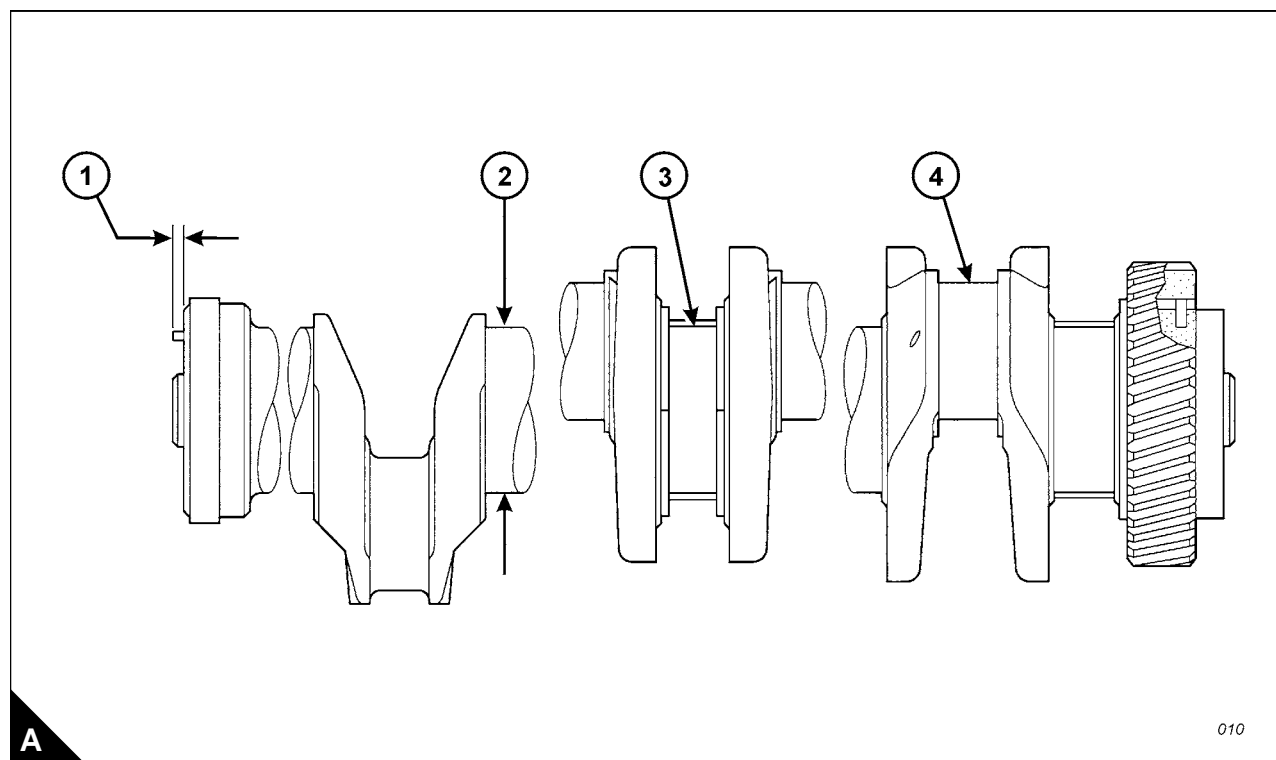
Piston ring gaps measured with the ring fitted in a new liner with a bore size 144,975 mm (5.7077 in):

Top piston ring (A4) . . . . .	0,4 +/- 0,1 mm (0.020 +/- 0.004 in)
Intermediate ring (A3) . . . . .	0,6 +/- 0,1 mm (0.002 +/- 0.004 in)
Oil control ring (A2) . . . . .	0,550 +/- 0,150 mm (0.0216 +/- 0.0059 in)
Width of groove for oil control ring in new piston . . . . .	3,02 +/- 0,010 mm (0.119 +/- 0.0004 in)
Thickness of a new oil control ring . . . . .	2,98 +/- 0,010 mm (0.117 +/- 0.0004 in)
Clearance between piston ring groove and new oil control ring . . . . .	0,04 +/- 0,023 mm (0.002 +/- 0.0009 in)
Maximum permissible clearance between piston ring groove and a used oil control ring . . . . .	0,15 mm (0.006 in)
Bore of piston crown bearing (A1) . . . . .	65,635 +/- 0,010 mm (2.5840 +/- 0.0004 in)
Gudgeon pin diameter (A1) . . . . .	59,975 +/- 0,005 mm (2.3612 +/- 0.0002 in)
Length of gudgeon pin . . . . .	113,20 +/- 0,15 mm (4.457 +/- 0.006 in)
Bore in connecting rod for small end bearing (A7) . . . . .	64,592 +/- 0,013 mm (2.5430 +/- 0.0005 in)
Bore of connecting rod small end bearing (A6) . . . . .	60,035 +/- 0,008 mm (2.3636 +/- 0.0003 in)
Bore in connecting rod for big end bearing shells (A5) . . . . .	103,2 +/- 0,013 mm (4.063 +/- 0.0005 in)
Distance between centres of big and small end bearings (A8) . . . . .	270,76 +/- 0,05 mm (10.660 +/- 0.002 in)



## Crankshaft, main bearings and flywheel

Diameter of main bearing journal (A2) ... ..	120,650 +/- 0,020 mm (4.7500 +/- 0.0008 in)
Journal undersize by 0,63 mm (0.025 in) ... ..	120,015 +/- 0,020 (4.7250 +/- 0.0008 in)
Journal undersize by 1,27 mm (0.050 in) ... ..	119,380 +/- 0,020 mm (4.7000 +/- 0.0008 in)
Clearance between a new bearing and the journal (A3) ... ..	0,091 to 0,186 mm (0.0036 to 0.0073 in)
Maximum permissible clearance between the bearing and journal ... ..	0,25 mm (0.010 in)
Diameter of main bearing bore .. ..	129,891 +/- 0,013 mm (5.1138 +/- 0.0005 in)
Diameter of main bearing bore, oversize by 0,63 mm (0.025 in) .	130,526 +/- 0,013 mm (5.1388 +/- 0.0005 in)
Diameter of connecting rod journal (A4) ... ..	97,0 +/- 0,020 mm (3.819 +/- 0.0008 in)
Journal undersize by 0,63 mm (0.025 in) ... ..	96,370 +/- 0,020 (3.794 +/- 0.0008 in)
Journal undersize by 1,27 mm (0.050 in) ... ..	95,730 +/- 0,020 mm (3.769 +/- 0.0008 in)
Clearance between a new bearing and the journal ... ..	0,062 to 0,160 mm (0.0024 to 0.0063 in)
Maximum permissible clearance between the bearing and journal ... ..	0,20 mm (0.008 in)
End-float of crankshaft ... ..	0,11 to 0,57 mm (0.004 to 0.022 in)
Maximum permissible end-float (with used bearings) ... ..	0,89 mm (0.035 in)
Maximum protrusion of dowel (A1) ... ..	6,4 mm (0.25 in)



## Crankshaft damper

Maximum permissible run-out of face of damper ... ..	2,03 mm (0.080 in)
--	--------------------



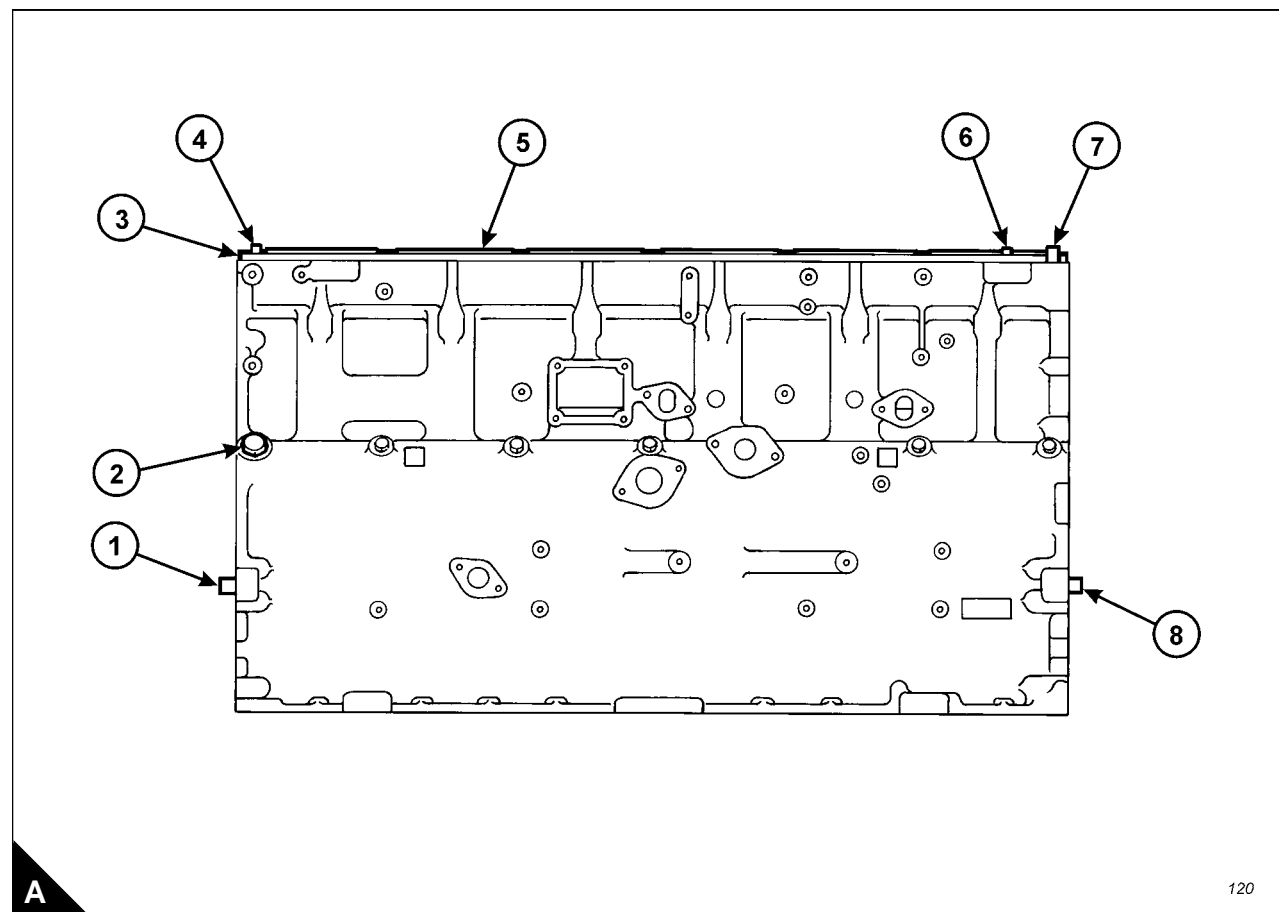
## Crankcase and cylinder liners

Thickness of spacer plate (A3) ... ..	8,585 +/- 0,025 mm (0.3380 +/- 0.0010 in)
Thickness of gasket fitted between spacer plate and crankcase ... ..	0,20 +/- 0,02 mm (0.008 +/- 0.0010 in)
Cylinder liner protrusion (A5) above the spacer plate ... ..	0,025 to 0,152 mm (0.0010 to 0.0060 in)
Maximum variation in each cylinder liner. ... ..	0,051 mm (0.0020 in)
Maximum average variation between adjacent cylinder liners ... ..	0,051 mm (0.0020 in)
Maximum variation between all cylinder liners ... ..	0,102 mm (0.0040 in)

Refer to Operation 7-3 for further cylinder liner information.

Protrusion of front cylinder head dowel (A6) above top face of crankcase ..	16,0 +/- 0,5 mm (0.63 +/- 0.02 in)
Protrusion of rear cylinder head dowel (A4) above top face of crankcase ..	18,5 +/- 0,5 mm (0.73 +/- 0.02 in)
Protrusion of oil transfer tube (A7) above top face of crankcase. ....	20,0 +/- 0,5 mm (0.79 +/- 0.02 in)
Protrusion of flywheel housing dowels (A1) from rear face of crankcase ...	19,1 +/- 0,5 mm (0.75 +/- 0.02 in)
Protrusion of gear case dowels (A8) from front face of crankcase.. ....	19,1 +/- 0,5 mm (0.75 +/- 0.02 in)
Plug (A2) must be tightened to a torque of.. ....	70 +/- 10 Nm (52 +/- 7 lbf ft)

The total flatness of the top face of the crankcase must be within 0,10 mm (0.004 in). The flatness must also be within 0,05 mm (0.002 in) for any 177,5 mm (6.99 in) section of the surface.



Continued

Distance from top of crankcase to centre of main

bearing bore (B1) ... 425,45 +/- 0,15 mm (16.750 +/- 0.006 in)

Minimum permissible (B1) ... 425,02 mm (16.733 in)

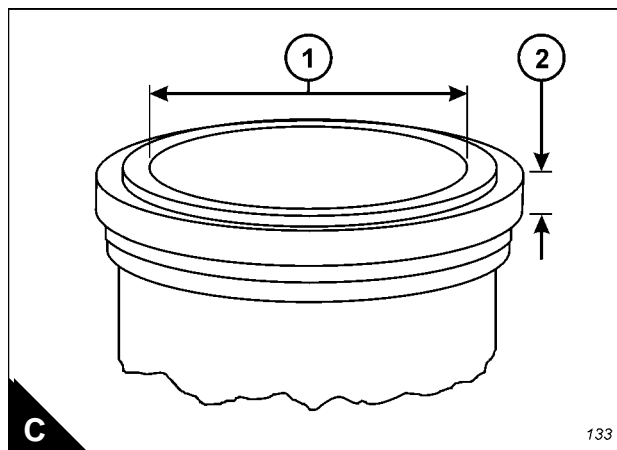
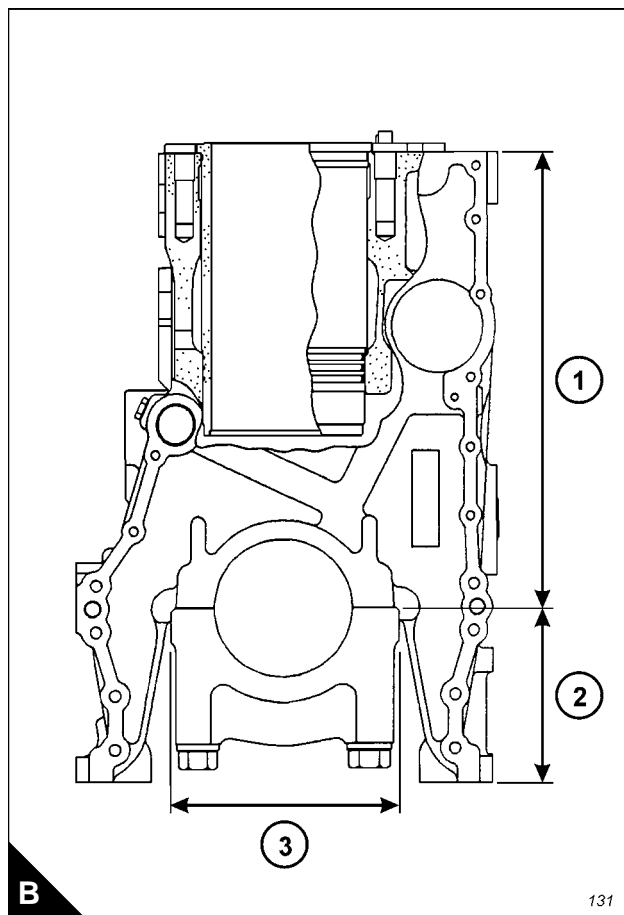
Distance from bottom of crankcase to centre of main

bearing bore (B2) ... 165,10 +/- 0,10 mm (6.500 +/- 0.004 in)

Bore in new cylinder liner (C1) ... 145 +/- 0,025 mm (5.71 +/- 0.0010 in)

Thickness of liner flange (C2) ... 8,890 +/- 0,020 mm (0.3500 +/- 0.0008 in)

Minimum thickness permissible (C2) ... 8,870 mm (0.3492 in)

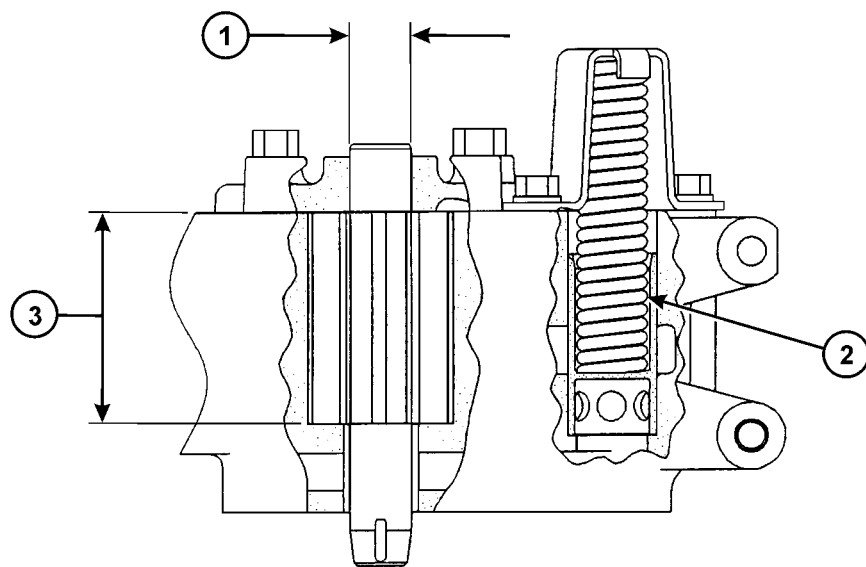


**Lubricating oil pump**

Diameter of shafts (A1) .....	22,217 +/- 0,005 mm (0.8747 +/- 0.0002 in)
Diameter of bores in cover for shafts.....	22,258 +/- 0,008 mm (0.8763 +/- 0.0003 in)
Length of gears (A3) .....	79,375 +/- 0,025 mm (3.1250 +/- 0.0010 in)
Depth of bores for gears (A3) .....	79,502 +/- 0,020 mm (3.1300 +/- 0.0008 in)

Spring (A2):

Test force. ....	150 +/- 8 Nm (110 +/- 6 lbf ft)
Length under test force .....	117,9 mm (4.64 in)
Free length after test .....	152,9 mm (6.02 in)
Outside diameter .....	27 mm (1.063 in)



A

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## Recommended torque figures

Exceptions to these torque figures are given in the Workshop Manual where necessary.

Before any components are fitted to the engine, ensure that they are in a new or close to new condition. Bolts or threads must not be worn or damaged. Components must be free from rust or other corrosion. Clean with a non-corrosive cleaner if necessary. Do not lubricate the threads of fasteners. Rust preventative which has been applied by the component supplier for shipping and storage is acceptable. Certain components may require an application of a particular lubricant, details are given in the Workshop Manual where relevant.

## Standard torque figures for metric fasteners

Thread size metric	Metric nuts and setscrews torque		
	Nm	lbf ft	kgf m
M6	12	9	0,9
M8	28	21	2,2
M10	55	41	4,5
M12	100	75	8,0
M14	124	120	13,0
M16	240	175	19,3
M20	460	340	46,9
M24	800	590	81,5
M30	1600	1180	163,1
M36	2700	2000	273,3

Thread size metric	Metric taperlock studs torque		
	Nm	lbf ft	kgf m
M6	8	6	0,81
M8	17	13	3,5
M10	35	26	4,5
M12	65	48	6,6
M16	110	80	11,2
M20	170	125	17,3
M24	400	300	40,7
M30	750	550	76,4
M36	1200	880	122,3

## Standard torque figures for imperial fasteners

Thread size inches	Imperial nuts and setscrews torque		
	Nm	lbf ft	kgf m
1/4	12	9	0,9
5/16	25	18	2,5
3/8	47	35	4,7
7/16	70	50	7,1
1/2	105	75	10,7
9/16	160	120	16,3
5/8	215	160	21,9
3/4	370	275	37,7
7/8	620	460	63,2
1	900	660	91,7
1 1/8	1300	960	132,5
1 1/4	1800	1320	183,5
1 3/8	2400	1780	244,7
1 1/2	3100	2280	316,1

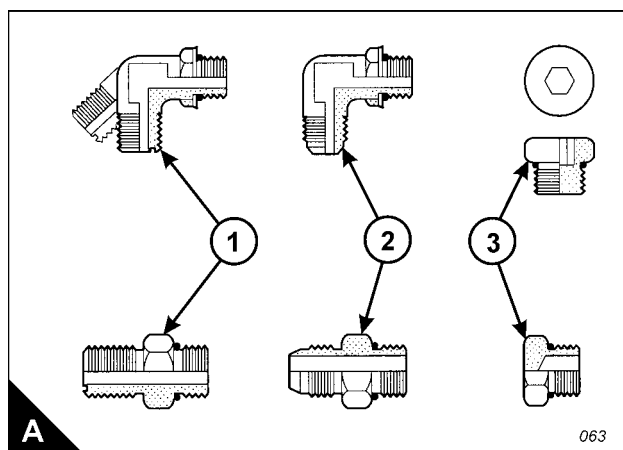
Thread size inches	Imperial taperlock studs torque		
	Nm	lbf ft	kgf m
1/4	8	6	0,8
5/16	17	13	1,7
3/8	35	26	3,5
7/16	45	33	4,5
1/2	65	48	6,6
5/8	110	80	11,2
3/4	170	125	17,3
7/8	260	190	26,5
1	400	300	40,7
1 1/8	525	390	53,5
1 1/4	750	550	76,4
1 3/8	950	700	96,8
1 1/2	1200	880	122,3

## Standard torque figures for 'O' ring face seal fittings and 37 degree flared fittings

Torque figures for ferrous straight thread 'O' ring fittings when connected to ferrous materials				
Outside diameter of nominal tube	Thread size Inches	Nm	lbf ft	kgf m
3,18 mm (0.125 in)	5/16 - 24	5,0	4	0,50
4,76 mm (0.188 in)	3/8 - 24	12	9	1,22
6,35 mm (0.250 in)	7/16 - 20	22	16	2,24
7,94 mm (0.312 in)	1/2 - 20	30	22	3,05
9,52 mm (0.375 in)	9/16 - 18	48	35	4,89
12,70 mm (0.500 in)	3/4 - 16	82	60	8,36
15,88 mm (0.625 in)	7/8 - 14	143	105	14,58
19,05 mm (0.750 in)	1 1/16 - 12	190	140	19,37
22,22 mm (0.875 in)	1 3/16 - 12	250	185	25,49
25,40 mm (1.000 in)	1 5/16 - 12	300	220	30,59
31,75 mm (1.250 in)	1 5/8 - 12	350	260	35,69
38,10 mm (1.500 in)	1 7/8 - 12	430	320	43,84
50,80 mm (2.000 in)	2 1/2 - 12	450	330	45,88

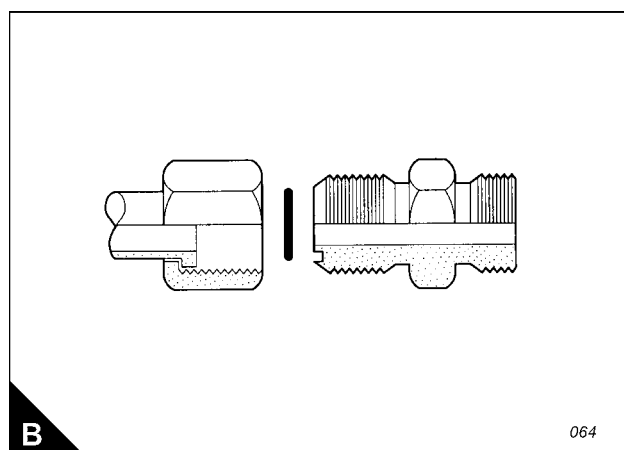
**Note:** For the table above, use 50 percent of the torque figure when the fitting, the plug or the port material is nonferrous.

Examples of relevant fittings are shown (A): 'O' ring face seal (A1), 37 degree flare (A2) and plug with a hexagon or socket-type head (A3).



**'O' ring face seal fittings**

Thread size inches	Torque figures for ferrous straight thread 'O' ring fittings (B)		
	Nm	lbf ft	kgf m
1/4	8	6	0,81
5/16	17	13	1,73
3/8	35	26	3,56
7/16	45	33	4,58
1/2	65	48	6,62
5/8	110	80	11,21
3/4	170	125	17,33
7/8	260	190	26,51
1	400	300	40,78
1 1/8	525	390	53,53
1 1/4	750	550	76,47
1 3/8	950	700	96,87
1 1/2	1200	880	122,36

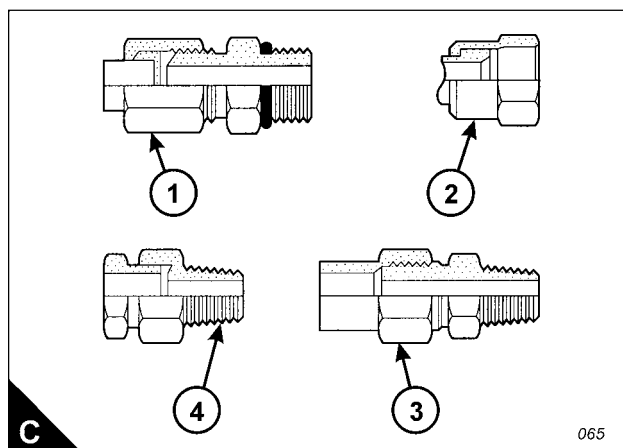


## Torque figures for flared and 'O' ring fittings

The torque figures given in the table below and "45 degree flared and 45 degree inverted flare fittings" on page 23 should be applied to the nut of the fittings which follow: 37 degree flared fittings (C1), 45 degree flared fittings (C3), inverted flared fittings (C2), 'O' ring fittings for a recessed drive, 'O' ring fittings for air conditioning and swivel nuts (C2). The figures should be used for applications which allow these working pressures: 7750 to 34450 kPa (1125 to 5000 lb/in<sup>2</sup>). The torque figure depends on the size and type of fitting.

Nuts for 37 degree flared fittings				
Outside diameter of nominal tube	Thread size Inches	Nm	lbf ft	kgf m
3,18 mm (0.125 in)	5/16	5,0)	4	0,50
4,76 mm (0.188 in)	3/8	11)	8	1,121
6,35 mm (0.250 in)	7/16	16	12	1,63
7,94 mm (0.312 in)	1/2	20	15	2,03
9,52 mm (0.375 in)	9/16	25	18	2,54
9,52 mm (0.375 in)	5/8	35	26	3,56
12,70 mm (0.500 in)	3/4	50	37	5,09
15,88 mm (0.625 in)	7/8	65	48	6,62
19,05 mm (0.750 in)	1 1/16	100	75	10,19
22,22 mm (0.875 in)	1 3/16	120	90	12,23
25,40 mm (1.000 in)	1 5/16	135	100	13,76
31,75 mm (1.250 in)	1 5/8	180	135	18,35
38,10 mm (1.500 in)	1 7/8	225	165	22,94
50,80 mm (2.000 in)	2 1/2	320	240	32,63

**Note:** For the table above, use 50 percent of the torque figure when the fitting, the plug or the port material is nonferrous.





**45 degree flared and 45 degree inverted flare fittings**

<b>45 degree flared and 45 degree inverted flare fittings</b>				
<b>Outside diameter of nominal tube</b>	<b>Thread size Inches</b>	<b>Nm</b>	<b>lbf ft</b>	<b>kgf m</b>
3,18 mm (0.125 in)	5/16	5,0	4	0,50
4,76 mm (0.188 in)	3/8	8	6	0,81
6,35 mm (0.250 in)	7/16	11	8	1,12
7,94 mm (0.312 in)	1/2	17	13	1, 73
9,52 mm (0.375 in)	5/8	30	22	3,05
11,11 mm (0.438 in)	11/16	30	22	3,05
12,70 mm (0.500 in)	3/4	38	28	3,87
15,88 mm (0.625 in)	7/8	50	37	5,09
19,05 mm (0.750 in)	1 1/16	90	65	9,17
22,22 mm (0.875 in)	1 1/4	100	75	10,19

## Tapered pipe thread fittings

Tapered pipe thread fittings			
Threads with pipe sealant (CV60891)			
Thread size Inches			
	Nm	lbf ft	kgf m
1/16 - 27	10 Nm (lbf ft)	7	1.01
1/8 - 27	16 Nm (lbf ft)	12	1.63
1/4 - 18	20 Nm (lbf ft)	15	2.03
3/8 - 18	35 Nm (lbf ft)	26	3.56
1/2 - 14	45 Nm (lbf ft)	33	4.58
3/4 - 14	60 Nm (lbf ft)	44	6.11
1 - 11 1/2	75 Nm (lbf ft)	55	7.64
1 1/4 - 11 1/2	90 Nm (lbf ft)	65	9.17
1 1/2 - 11 1/2	110 Nm (lbf ft)	80	11.21
2 - 11 1/2	130 Nm (lbf ft)	95	13.25

Tapered pipe thread fittings			
Threads without pipe sealant (CV60891)			
Thread size Inches			
	Nm	lbf ft	kgf m
1/16 - 27	10 Nm (lbf ft)	7	1.01
1/8 - 27	16 Nm (12 lbf ft)	12	1.63
1/4 - 18	25 Nm (lbf ft)	18	2.54
3/8 - 18	45 Nm (lbf ft)	33	4.58
1/2 - 14	60 Nm (lbf ft)	44	6.11
3/4 - 14	75 Nm (lbf ft)	55	7.64
1 - 11 1/2	90 Nm (lbf ft)	65	9.17
1 1/4 - 11 1/2	110 Nm (lbf ft)	80	11.21
1 1/2 - 11 1/2	130 Nm (lbf ft)	95	13.25
2 - 11 1/2	160 Nm (lbf ft)	120	16.31

**Note:** For the table above, use 50 percent of the torque figure when the fitting, the plug or the port material is nonferrous.

## Torque figures for standard hose clamps of the worm drive band type

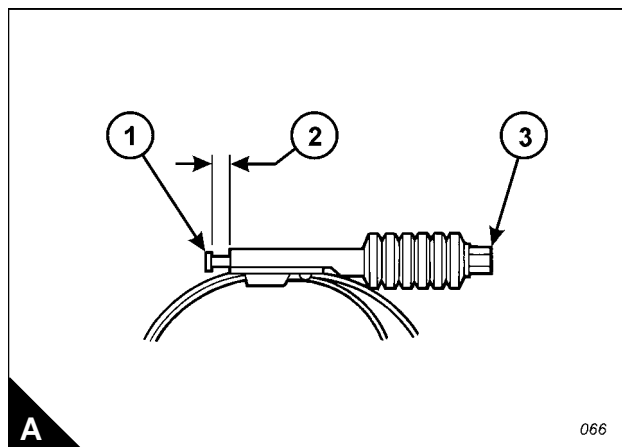
Torque figure for initial installation on a new hose			
Width of clamp	Nm	lbf ft	kgf m
7,9 mm (0.31 in)	0,9	8	0.09
13,5 mm (0.53 in)	4,5	40	0.45
15,9 mm (0.63 in)	7,5	65	0.76
Width of clamp	Torque figure for used clamp		
7,9 mm (0.31 in)	0,7	6	0.07
13,5 mm (0.53 in)	3,0	27	0.30
15,9 mm (0.63 in)	4,5	40	0.45

## Torque figures for constant torque hose clamps

Use a torque wrench for the correct installation of a constant torque hose clamp. For a constant torque hose clamp to be installed correctly, these conditions must exist:

The screw tip (A1) must extend by 6,35 mm (0.250 in) beyond the housing (A2).

The belleville washers must be collapsed almost flat after the screw (A3) has been tightened to a torque of 11 +/- 1 Nm (98 +/- 9 lb in).



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## Thread sealant

When setscrews or studs are fitted into holes which are tapped through the cylinder block, a suitable sealant must be used to prevent leakage.

Micro encapsulated anaerobic sealant (M.E.A.S) fasteners have been introduced instead of jointing compounds or other sealants when the fasteners are fitted in through holes into oil or coolant passages. The identification of these fasteners, as supplied, is by a red, blue, or other colour sealant around the fastener threads.

With M.E.A.S. sealed studs, the sealed end must be fitted into the cylinder head / cylinder block etc. Ensure that the threaded holes have a 1,59 mm (0.0625 in) 45° chamfer, to ensure that when the new fasteners are fitted the M.E.A.S. sealant is not removed. If the fasteners have to be removed and fitted again, the threads must be cleaned and a suitable sealant used.

**Note:** New setscrews have sealant applied by the manufacturer to the first 13,0 mm (0.50 in) of the threads. If the setscrews are to be used again, clean the old sealant from the male and female threads and apply new sealant, (POWERPART Threadlock and Nutlock) to the setscrews.

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## Cylinder head assembly

### General information

**Warning!** *Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.*

The cylinder head is a single-piece cast iron component. The camshaft is mounted in the cylinder head and runs in shell bearings. The bearings are pressed into each journal and are lubricated under pressure. Bridge piece guides have been eliminated as floating valve bridges have been utilised.

Special thermal sleeves manufactured from stainless steel are fitted to the exhaust ports. These reduce the amount of heat transferred to the cooling system and direct the thermal energy to the turbocharger.

The electronic fuel unit injectors are mounted in stainless steel sleeves which have been pressed into the injector bores of the cylinder head.

The operations to remove and to fit valve seat inserts and to remove and to fit camshaft bearings are not included as specialist equipment is required. It is recommended that operators take advantage of the Perkins service exchange scheme if these procedures become necessary.

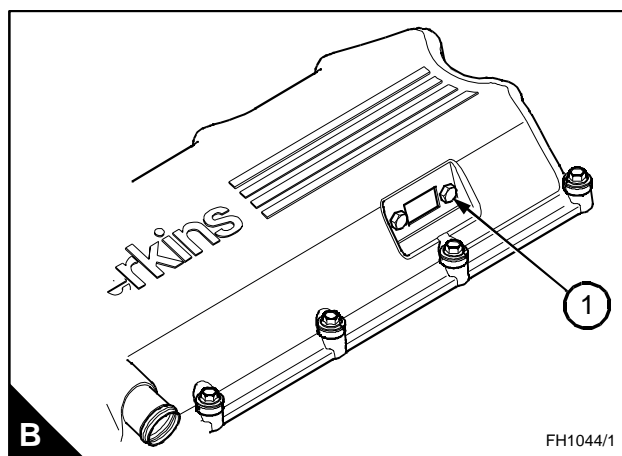
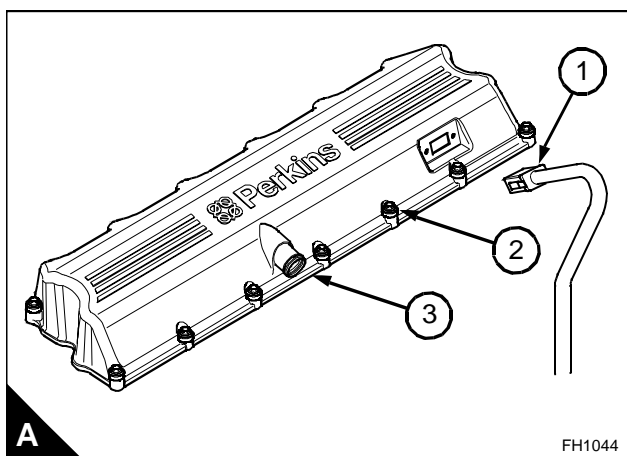
## Rocker cover

To remove

### Operation 3-1

**Warning!** The electrical circuit for the fuel injector units operates on 110 volts. Do not work on the fuel injector units unless the power supply to the ECM has been disconnected.

- 1 Remove the engine breather pipe, see Operation 9-1.
- 2 Disconnect the outer wiring harness (A1) from the rocker cover.
- 3 Remove the two setscrews (B1).
- 4 Loosen the fasteners (A2) fully which retain the rocker cover (A3), but do not remove the setscrews from the assembly; allow them to be retained by the seal.

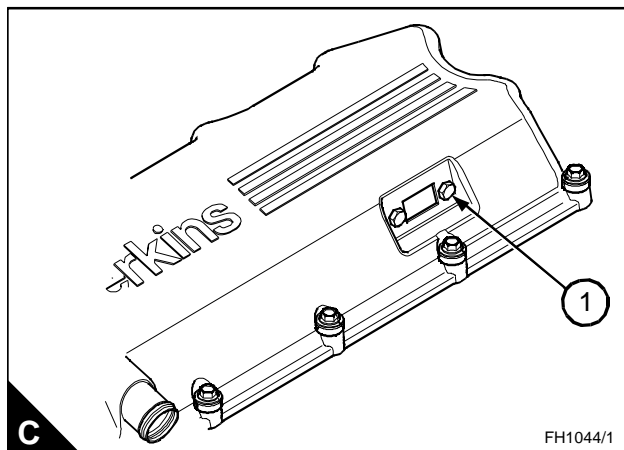
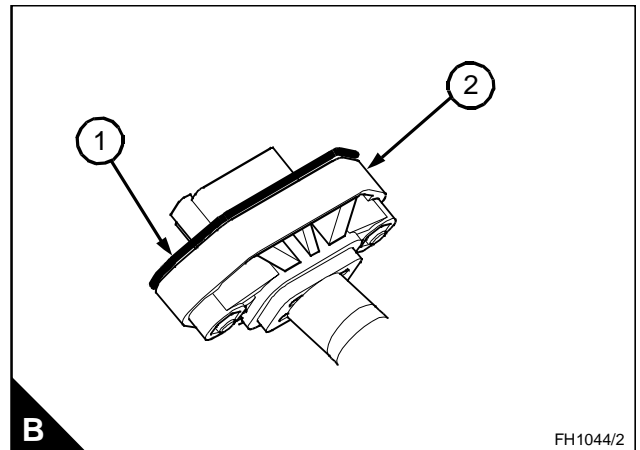
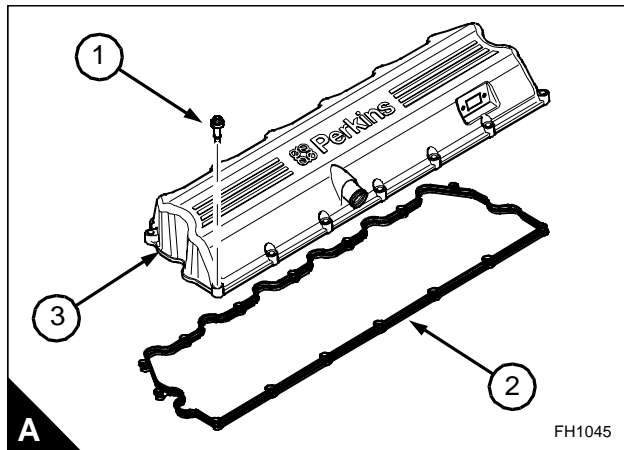


- 5 Remove the inner wiring harness on the rocker cover, see Operation 14-7.
- 6 Remove the rocker cover (A3).
- 7 Inspect the seal of the rocker cover and renew if worn or damaged.

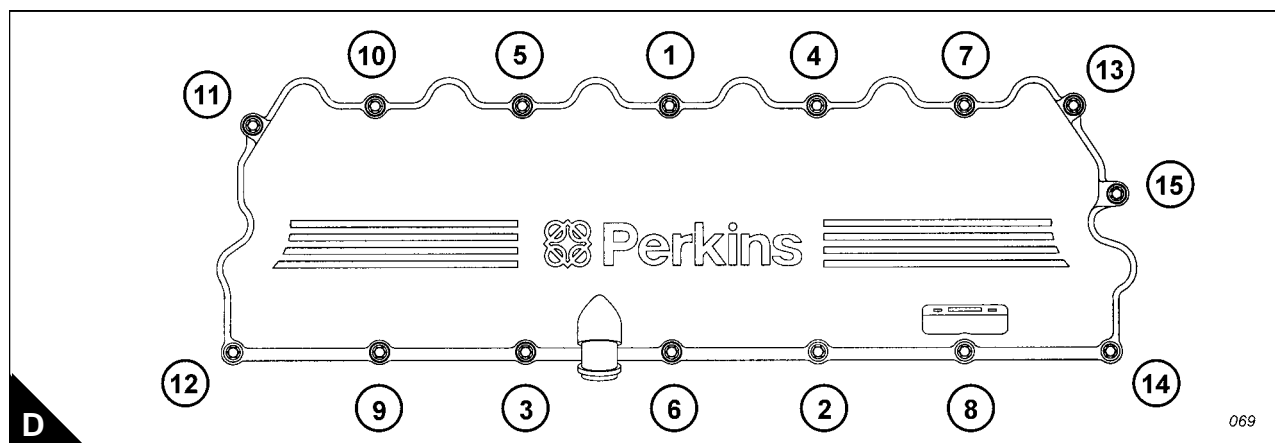
## To fit

## Operation 3-2

- 1 Ensure that the rocker cover and the groove for the joint are clean and free from oil and grease.
- 2 Fit a new joint (A2) into the rocker cover (A3).
- 3 Check the condition of the fasteners, renew as required.
- 4 Fit the fasteners (A1) through the rocker cover (A3) and into the seal (A2).
- 5 Check the joint (B1) and renew if necessary. Align the plug socket (B2) to the rocker cover.
- 6 Fit the setscrews (C1) and tighten securely.
- 7 Clean the seal face of the cylinder head and fit the rocker cover assembly.

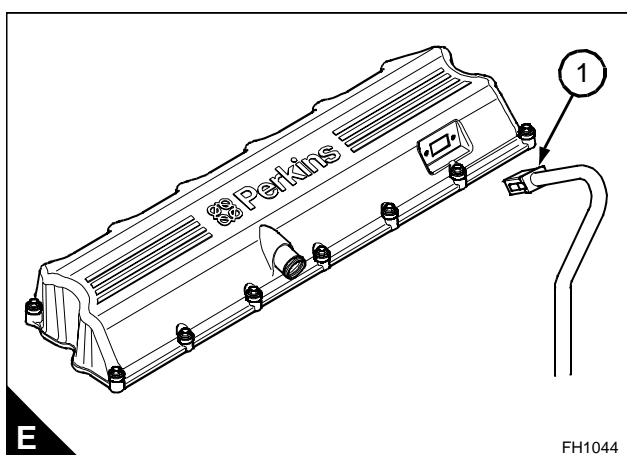
*Continued*

**8** Secure the rocker cover assembly to the cylinder head with the fasteners and tighten in sequence (D) to 20 Nm (15 lbf ft) 2.03 kgf m.



**9** Fit the engine breather pipe, see Operation 9-1.

**10** Connect the outer wiring harness connector (E1).



**11** Connect the power supply.



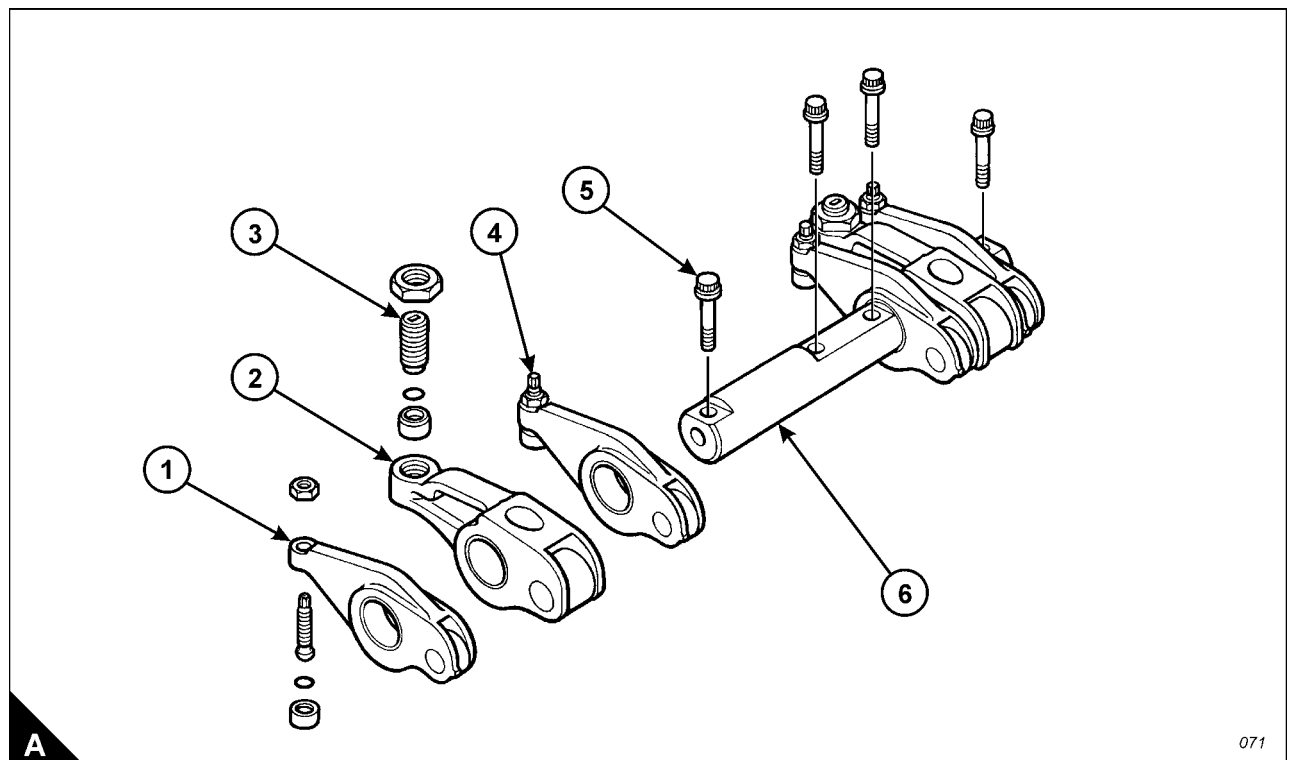
**Rocker lever and rocker shaft assemblies**

To remove and to fit

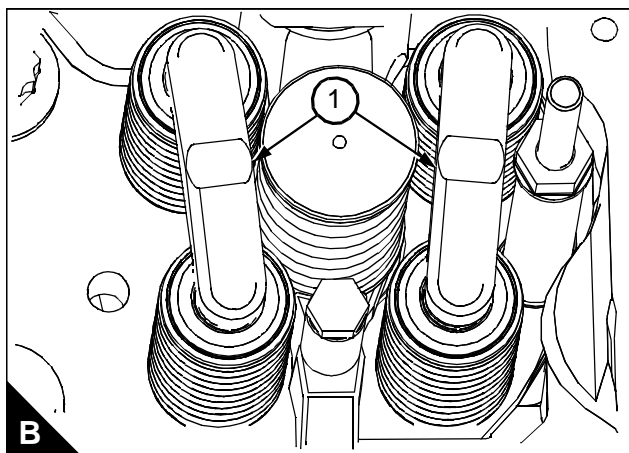
**Operation 3-3****To remove**

**Warning!** The rocker levers and injection lever can rotate on the shaft when remove from the cylinder head. Do not allow the levers to rotate as they may injure you.

- 1 Remove the rocker cover, see Operation 3-1.
- 2 Mark each levers to the correct cylinder number in order to help install the assembly.
- 3 Remove the four setscrews (A5) and remove the rocker lever assembly from the cylinder head.

*Continued*

4 Mark the bridge pieces (B1) to the correct cylinder number in order to help install the assembly and remove them.



#### To fit

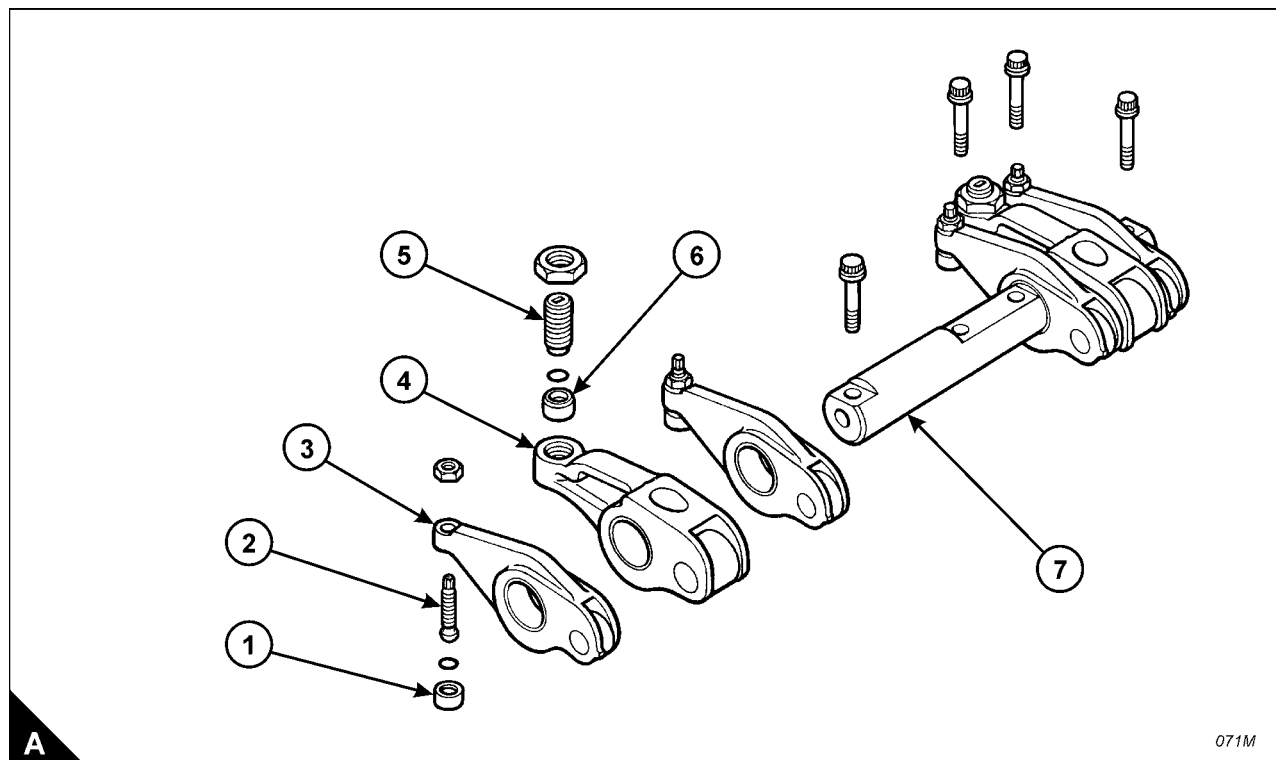
- 1 Check the bridge pieces (B1) and renew if necessary.
- 2 Align and fit the bridge pieces to the valves.
- 3 Loosen the adjustment screws (A3 and A4) of each of the rocker levers which have been removed. Install the rocker shaft assembly in the reverse order to removal.
- 4 Align the rocker lever assembly to the correct cylinder.
- 5 Fit the four setscrews (A5) and tighten to 109 Nm (80 lbf ft) 11,11 kgf m.
- 6 Set the tappet clearances, see Operation 3-5.
- 7 Check/adjust the fuel unit injectors, see Operation 11-2.
- 8 Fit the rocker cover, see Operation 3-2.

## To dismantle and to assemble

## Operation 3-4

**To dismantle**

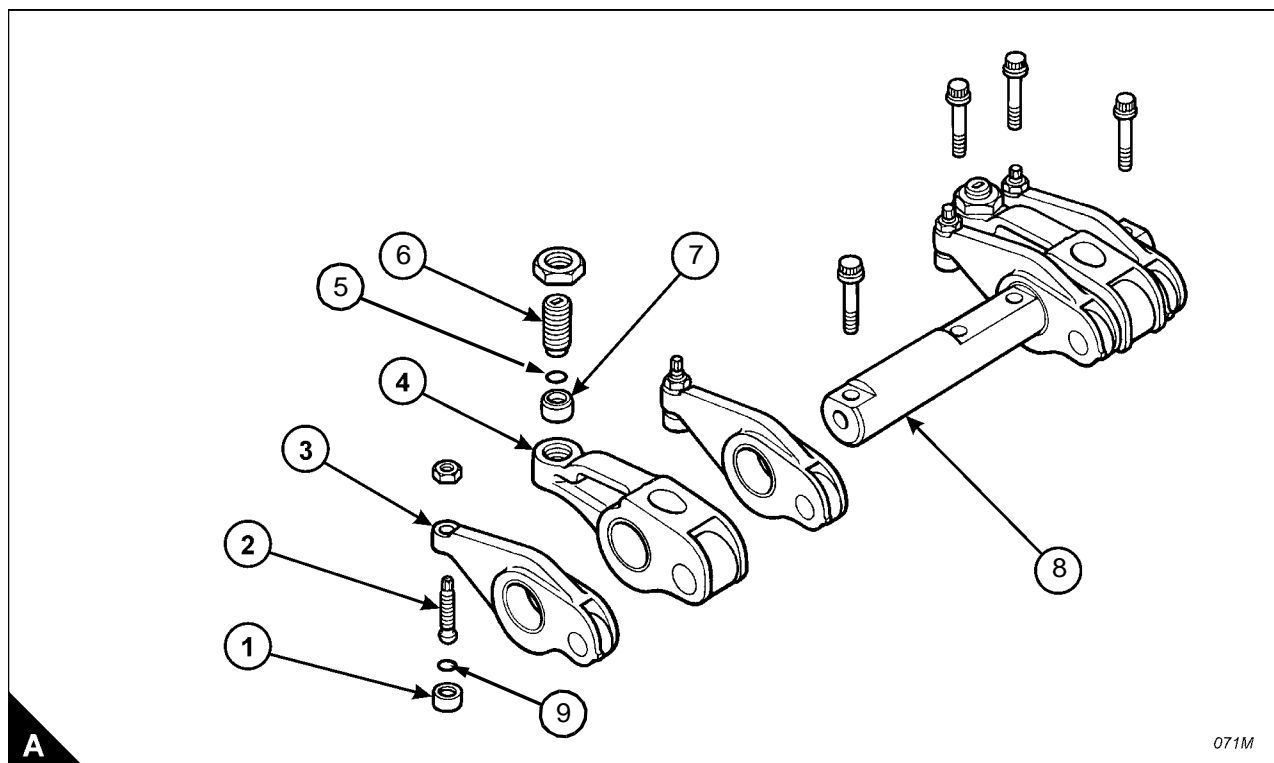
- 1 Ensure that all levers are marked to their correct cylinder before they are dismantled.
- 2 Slide the valve rocker levers (A3) and the unit injector rocker levers (A4) from the shaft (A7).
- 3 Remove the button (A1) from the adjustment screw (A2) in the valve rocker lever (A3).
- 4 Remove the button (A6) from the adjustment screw (A5) in the unit injector rocker lever (A4).



**To assemble**

**Note:** Check the condition of all components and renew as necessary.

- 1 If removed, install new 'O' ring (A9) in the buttons (A1).
- 2 If removed, install new 'O' ring (A5) in the buttons (A6).
- 3 Use a suitable tool to hold the rocker lever. Fit the 'O' ring seal and button (A1) on the round end of the adjustment screw (A2).
- 4 Ensure that the 'O' ring seal and button (A1) is fitted securely into adjustment screw (A2).
- 5 Fit the 'O' ring seal (A5) into the button (A7).
- 6 Ensure that the 'O' ring seal and button (A7) is fitted securely into adjustment screw (A6).
- 7 Fit the assembled rocker levers onto the shafts (A8). Ensure that they are fitted to their original positions.



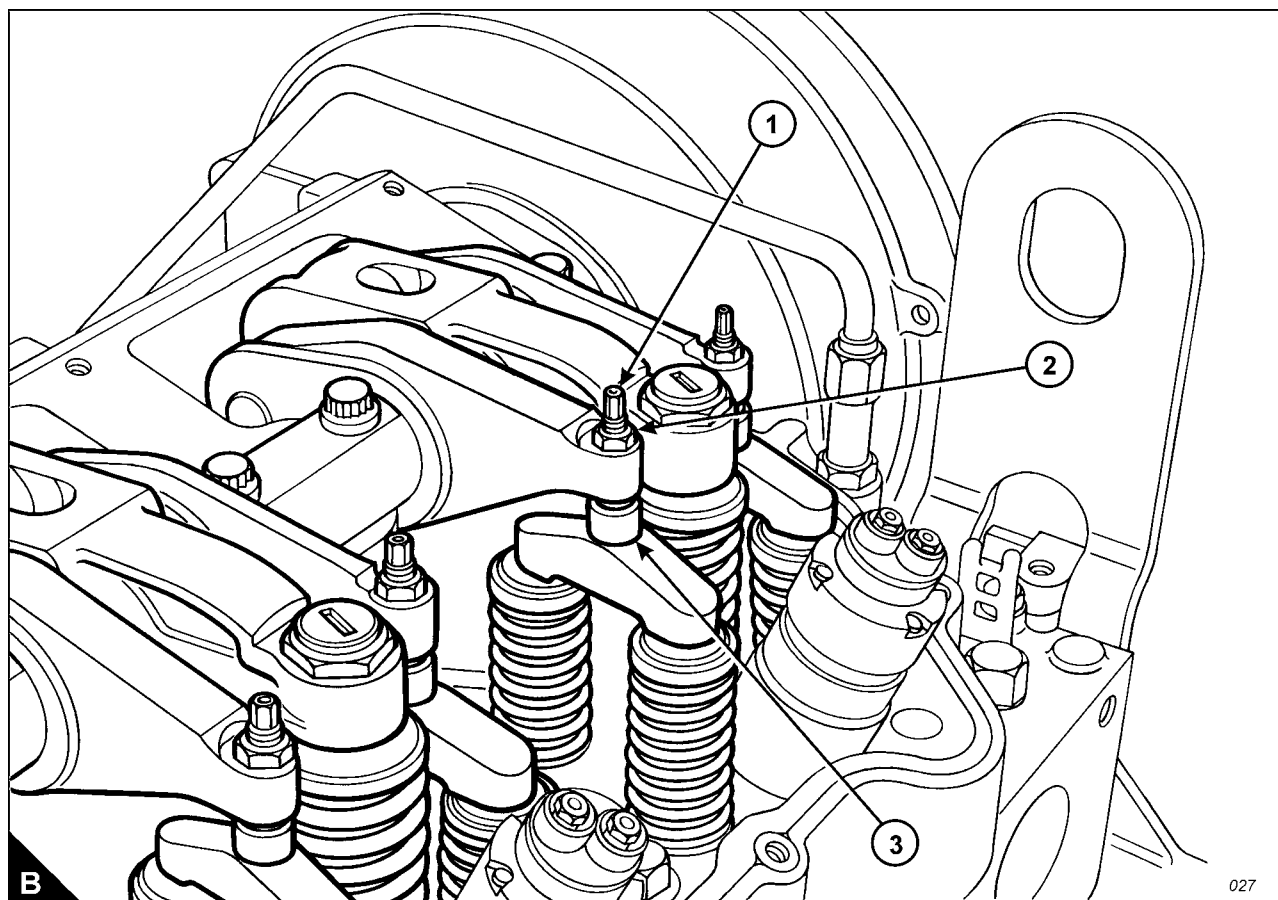
## Valve tip clearance

### How to check/adjust the tappet clearances

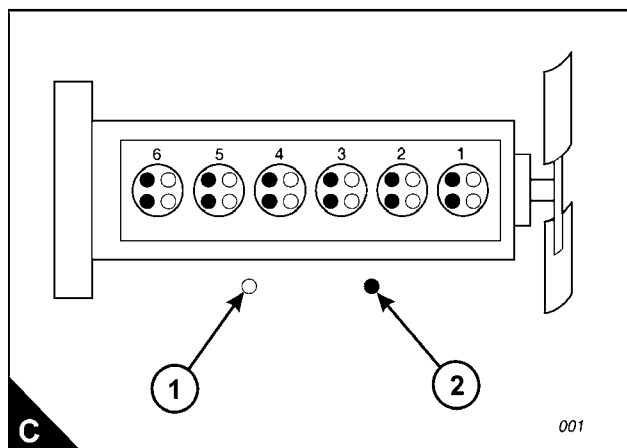
### Operation 3-5

The tappet clearance is measured between the rocker levers and the top of the valve bridge pieces. The engine must be stopped and the engine must be cold. The correct clearance for the inlet valve is 0,38 mm (0.015 in) and 0,76 mm (0.030 in) for the exhaust valve. Refer also to Operation 11-2.

- 1 Set the engine to TDC on compression stroke, see Operation 8-1.
- 2 Ensure that the roller of the rocker lever is fully against the camshaft lobe.
- 3 Inserted the feeler gauge between the valve bridge piece and the rocker lever button (B3), in order to check the tappet clearances for the inlet valves (C1) on cylinders 1, 2 and 4. Adjust the clearances if necessary. Check the tappet clearance for the exhaust valves (C2) on cylinders 1, 3 and 5, and adjust the clearances if necessary.



*Continued*

**Notes:**

- Move each valve bridge piece before the feeler gauge is inserted to reduce the effect of the oil film.
  - During the procedure, ensure that the feeler gauge is fully inserted
- 4 After each unit has been adjusted, tighten the lock nut (B2) of the adjustment screw (B1) to a torque of 30 Nm (22 lbf ft) 3.05 kgf m.
  - 5 Remove the timing setscrew and rotate the flywheel by 360 degrees so that the number 6 piston is at TDC on its compression stroke. Insert the timing setscrew into the threaded hole.
  - 6 Check the tappet clearances for the inlet valves (C1) on cylinders 3, 5 and 6. Adjust the clearances if necessary. Check the tappet clearances for the exhaust valves (C2) on cylinders 2, 4 and 6, and adjust the clearances if necessary.
  - 7 After each unit has been adjusted, tighten the lock nut of the adjustment screw to a torque of 30 Nm (22 lbf ft) 3.05 kgf m.
  - 8 Check again the tappet clearances for all six cylinders.
  - 9 Remove the timing setscrew from the flywheel, see Operation 8-1

## Cylinder head assembly

To remove and to fit

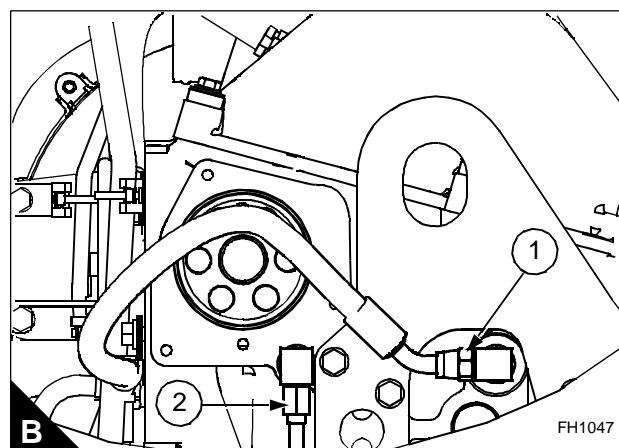
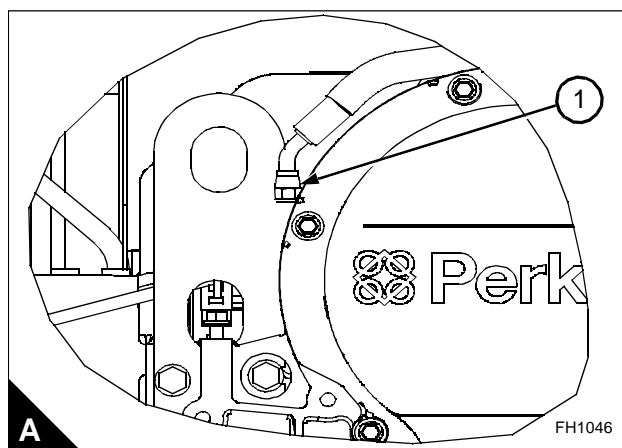
Operation 3-6

### Special requirements

Special tools		Consumable products	
Description	Part number	Description	Part number
Guide bolt, camshaft gear	GE50019	POWERPART Special lubricant	CV60895
Socket, cylinder head bolt	GE50020	POWERPART Retaining compound	21820 638
Lifting bracket	VP12712		

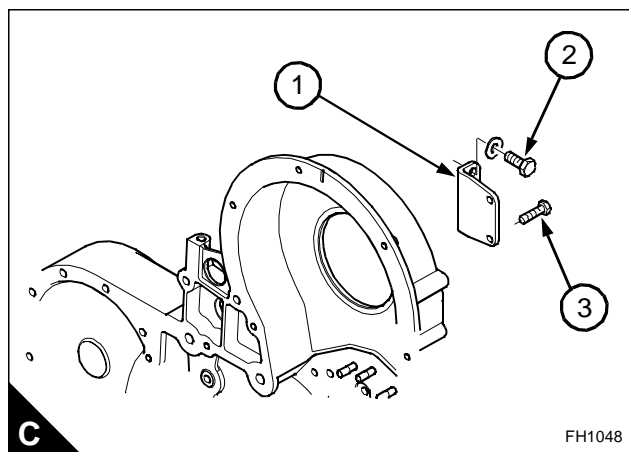
### To remove

- 1 Disconnect the power supply.
- 2 Disconnect the fuel lines from the front (A1) and rear (B1) of the cylinder head. Fit temporary covers to the fuel lines and also to the ports on the cylinder head.



- 3 Disconnect the oil supply pipe (B2).
- 4 Drain the engine coolant into a suitable container. Refer to the Users Handbook TPD1516.
- 5 Remove the thermostat housing, see Operation 12-12.
- 6 As necessary, remove the intake system see Operation 9-3.
- 7 Remove the exhaust manifold, see Operation 9-9.
- 8 Remove the rocker lever and rocker shaft assemblies, see Operation 3-3.
- 9 Remove the electronic fuel unit injectors, see Operation 11-1.
- 10 Remove the gear case cover, see Operation 6-1.
- 11 Disconnect the electrical connection to the cylinder head sensor, see Operation 14-9, Operation 14-11 and Operation 14-13.

Continued

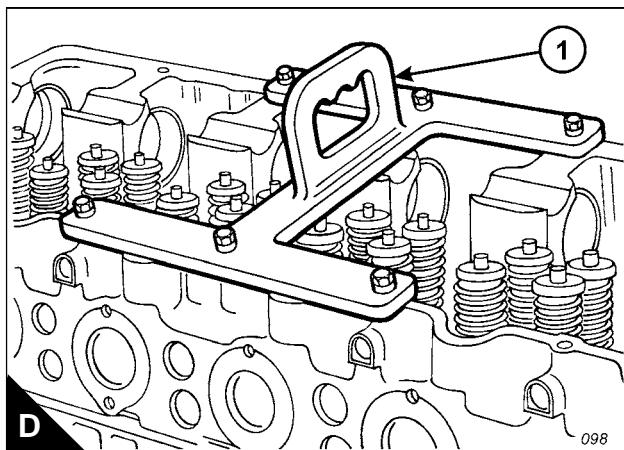


**12** Remove the setscrews (C2) and (C3), remove the support bracket (B1) which is fitted between the gear case and the cylinder head.

**13** Remove the camshaft gear, see Operation 6-2.

**14** Remove the cylinder head setscrews; use the special socket GE50020.

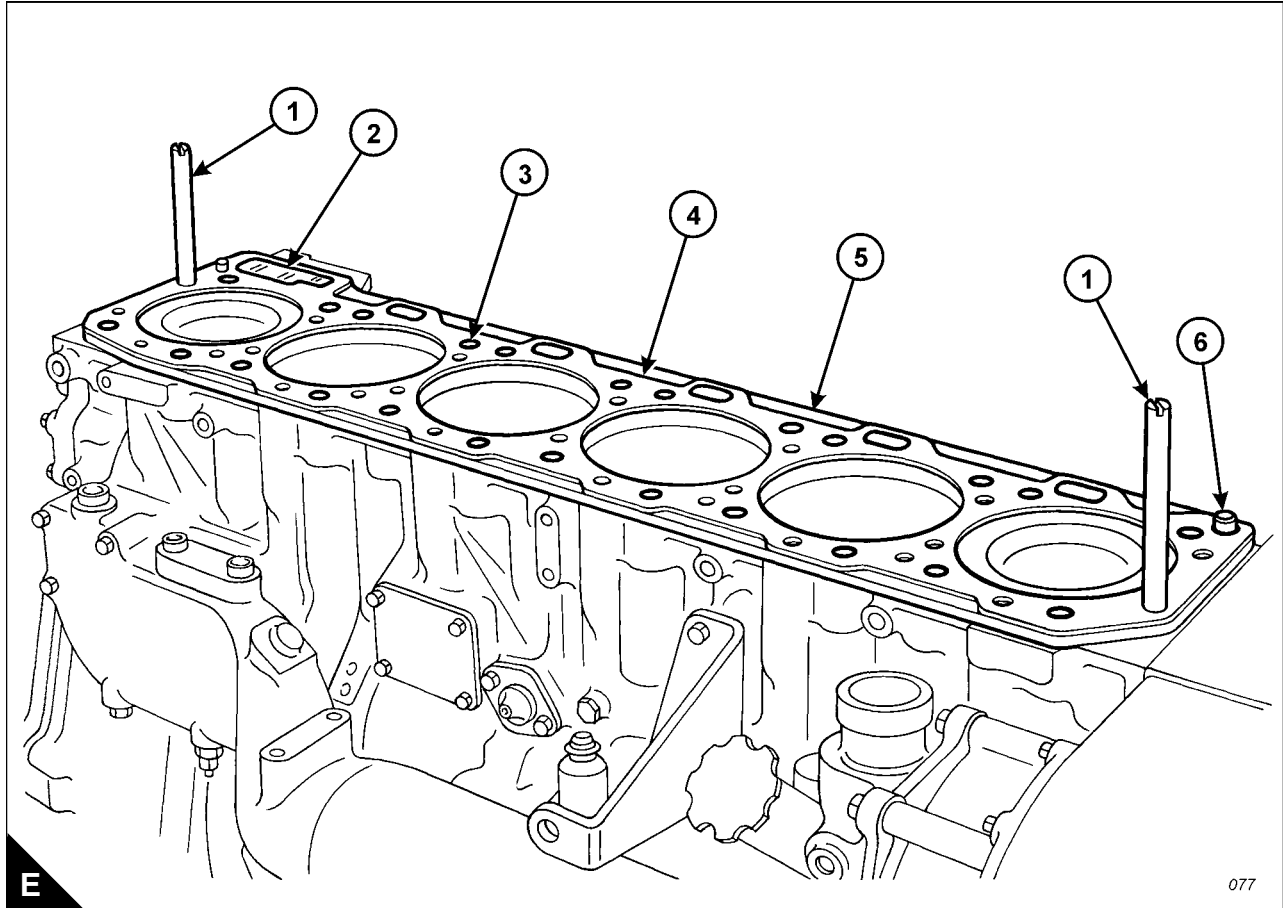
**15** Fit the lifting bracket (D1) VP12712 to the cylinder head and use suitable lift equipment in order to remove the cylinder head. The cylinder head weighs approximately 148 kg (325 lb).



*Continued*



- 16 Remove the cylinder head gasket (E4).
- 17 Remove the 'O' ring from the oil transfer tube (E6) and remove the 24 coolant seals (E3).
- 18 Remove the seal (E2).
- 19 Remove the spacer plate (D5) and discard the spacer plate gasket.
- 20 Remove the second 'O' ring from the oil transfer tube (E6).



## To fit

## Special requirements

Special tools	
Description	Part number
Lifting bracket	VP12712
Special socket	GE50020

1 If the oil transfer tube (A6) has been removed, apply retaining compound, 21820 638, and insert it in the crankcase. It must protrude from the top face of the crankcase by 20,0 +/- 0,5 mm (0.79 +/- 0.02 in). Remove any excess compound and ensure that the bore of the oil transfer tube is clean.

2 If the rear dowel has been removed, apply POWERPART retaining compound, 21820638, and insert it in the crankcase. It must protrude from the top face of the crankcase by 18,5 +/- 0,5 mm (0.73 +/- 0.02 in).

3 If the front dowel, close to the oil transfer tube, has been removed, it must be fitted in a dry condition. It must protrude from the top face of the crankcase by 16,0 +/- 0,5 mm (0.63 +/- 0.02 in).

**Note:** Ensure that the spacer plate and the machined surface of the cylinder block are clean and free from dirt and gasket material. Both surfaces of the spacer plate gasket and the top of the cylinder block must be clean. Do not use a gasket adhesive on the surfaces.

4 Fit suitable guide studs (A1) to the cylinder block. Fit a new spacer plate gasket over the dowels in the cylinder block.

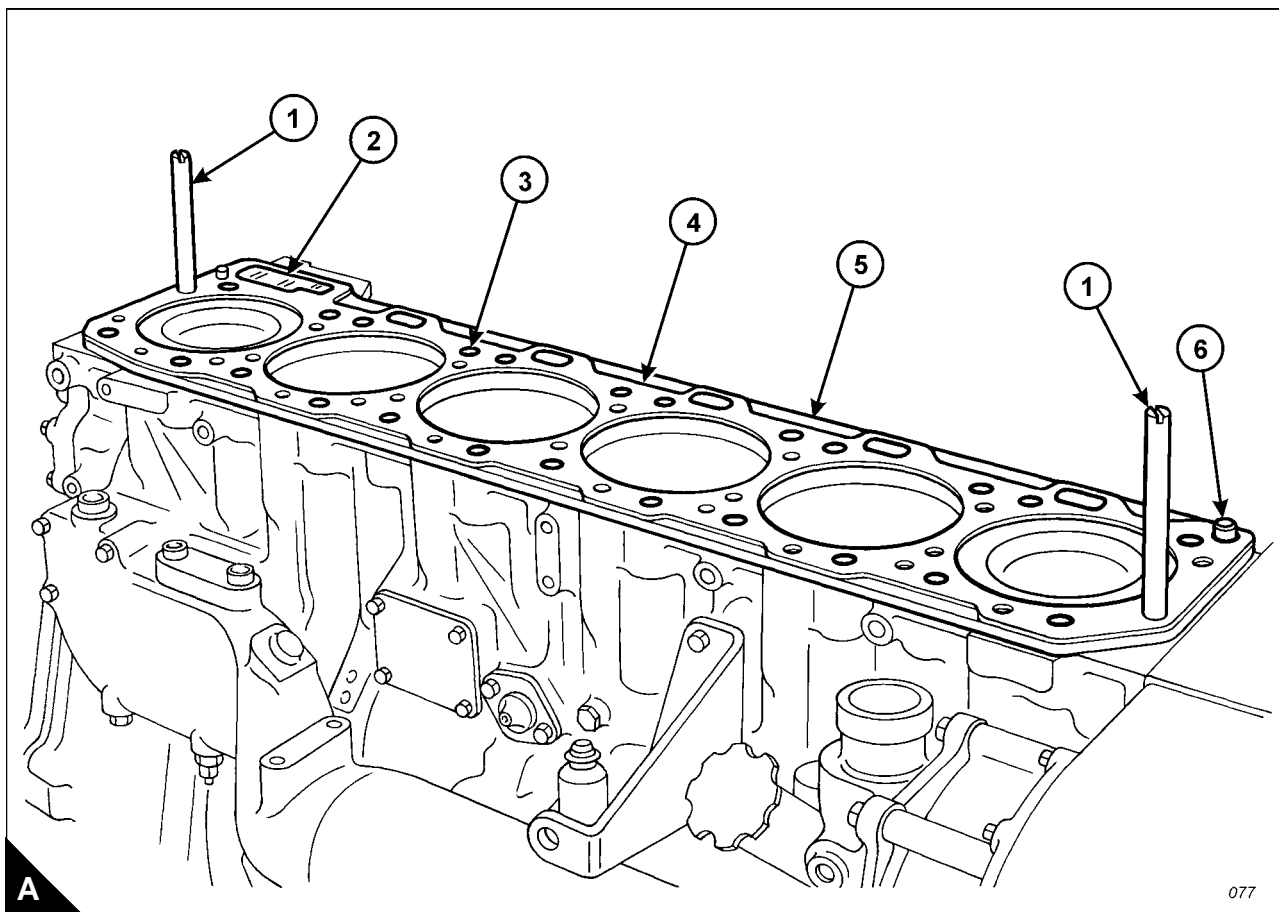
**Note:** Apply a small amount of clean engine lubricating oil to the seals and 'O' rings before installation.

5 Fit two new 'O' ring seals to the oil transfer tube (A6).

6 Fit the spacer plate (A5) and fit the second 'O' rings to the oil transfer tube (A6). Fit the 24 coolant seals (A3) and a new seal (A2) to the oil drain passage.

7 Check, and if necessary adjust, the protrusion of the cylinder liners, see Operation 7-3.

8 Fit a new cylinder head gasket (A4) onto the spacer plate.

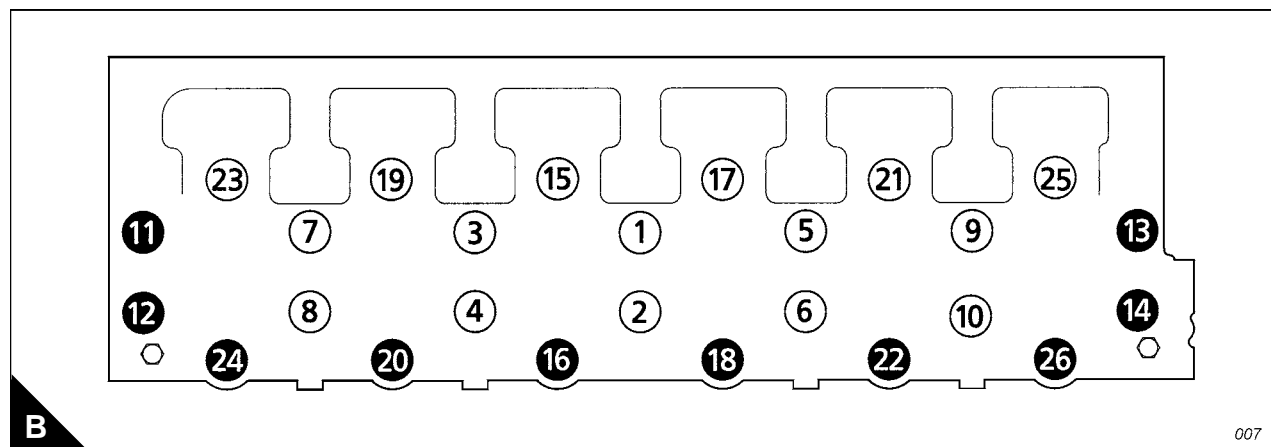


Continued

**9** Fit the lifting bracket VP12712 to the cylinder head. Use suitable lift equipment in order to fit the cylinder head onto the spacer plate.

**10** Apply POWERPART special lubricant CV60895 to the washers, the threads and under the heads of the setscrews and fit the cylinder head setscrews and washers. The long setscrews must be fitted at the positions shown in the black circles (B). Use the special socket GE50020 and the procedure which follows to tighten the setscrews:

- a. Tighten the cylinder head setscrews in the sequence (B) to a torque of 270 Nm (200 lbf ft) 27,5 kgf m.
- b. Tighten the cylinder head setscrews in the sequence (B) to a torque of 450 Nm (333 lbf ft) 45,8 kgf m.
- c. Tighten again, the cylinder head setscrews in the sequence (B) to a torque of 450 Nm (333 lbf ft) 45,8 kgf m.



**11** Fit the camshaft gear, see Operation 6-3.

**Caution:** After the cylinder head assembly has been removed and fitted, it is necessary to check the backlash between the camshaft and the adjustable idler gears, see Operation 6-6. Incorrect adjustment can cause damage to components.

**12** Fit the gear case cover, see Operation 6-1.

**13** Fit the support bracket between the cylinder head and the gear case.

**14** Fit the electronic fuel unit injectors, see Operation 11-1.

**15** Fit the rocker lever and shaft assemblies, see Operation 3-3.

**16** Fit the exhaust manifold, see Operation 9-9.

**17** As necessary, fit the intake system, see Operation 9-4.

**18** Fit the thermostat housing, see Operation 12-12.

**19** Remove the covers from the fuel lines and from the fuel line ports on the cylinder head. Connect the fuel lines to the cylinder head and attach any relevant clamps. Connect the oil supply pipe.

**20** Eliminate air from the fuel system, see Operation 11-7.

**21** Fit the sensor and connect the cable, see Operation 14-10, Operation 14-12 and Operation 14-14.

**22** Fill the cooling system.

**23** Connect the power supply.

## Valve springs

To remove and to fit

### Operation 3-7

#### Special requirements

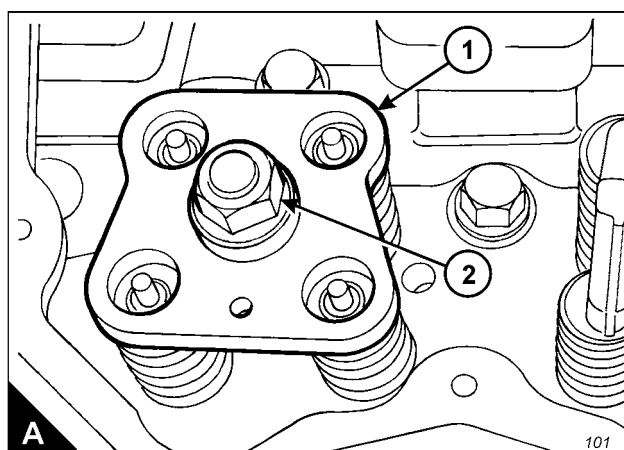
Special tools	
Description	Part number
Valve spring compressor	GE50026

#### To remove

**Warning!** Wear eye protection during this operation.

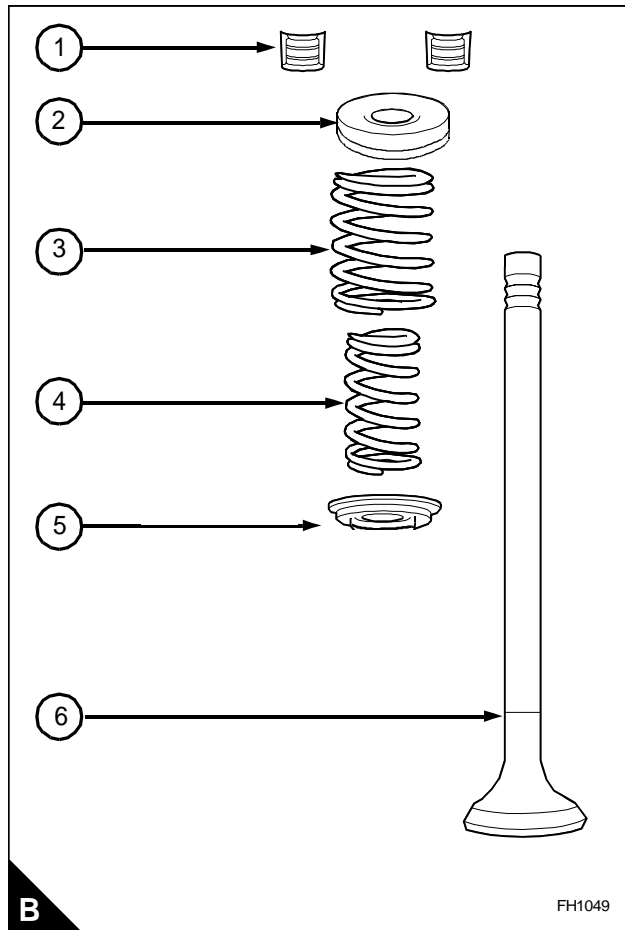
#### Cautions:

- This procedure must only be carried out by a person with the correct training.
  - The valve springs can be removed with the cylinder head either fitted to or removed from the engine. The procedure given, is for use when the cylinder head is fitted to the engine. Before any components are removed, ensure that the relevant piston is set to the top of its compression stroke. If the piston is not at this position, the valves can fall into the cylinder liner.
  - If a valve falls into the cylinder liner, the cylinder head must be removed.
- 1 Remove the rocker lever and rocker shaft assemblies, see Operation 3-3.
  - 2 Remove the electronic fuel unit injectors, see Operation 11-1.
  - 3 Set the piston for the relevant valve spring assembly to the top of its compression stroke.
  - 4 Use the hold-down clamp from the electronic fuel unit injector to secure the valve spring compressor, GE50026, to the cylinder head.
  - 5 Insert the stud and base of the valve spring compressor into the bore of the fuel injector sleeve. Use the setscrew and clamp from the electronic fuel unit injector to secure the stud and base to the cylinder head. Fit the compressor plate (A1) over the stud and fit the thrust bearing, the washer and the nut (A2)



Continued

- 6 Tighten the nut until the collets are loose on the valves.
- 7 Remove two collets (B1) from each valve.
- 8 Slowly loosen the nut, then remove the nut, washer, thrust bearing and plate.
- 9 Mark the springs in order to help assembly.
- 10 Remove the rotocoils (B2), the two valve springs (B3) and (B4). Remove the washer (B5) from each valve (B6).

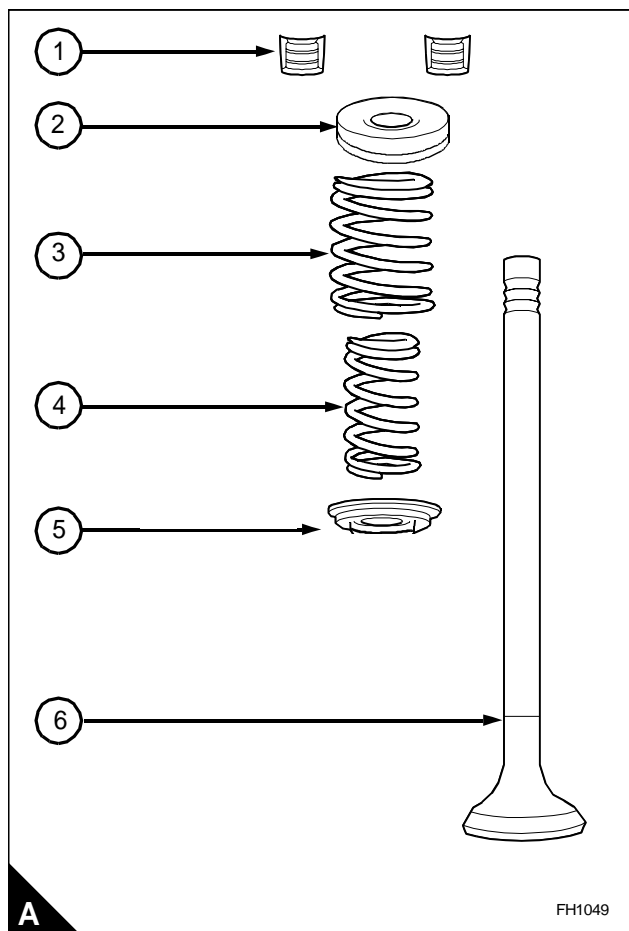


If necessary remove the valve stem seal, see Operation 3-8.

- 11 Inspect the valve springs, refer to Chapter 2, Specifications for the correct dimensions and spring force.

**To fit**

- 1 If removed fit new valve stem seal, see Operation 3-8.
- 2 Apply clean engine lubricating oil to the relevant valve stems (A6).
- 3 Fit the washer (A5) and both the valve spring (A4) and (A3). Fit the rotocoil (A2) to the valve assembly.



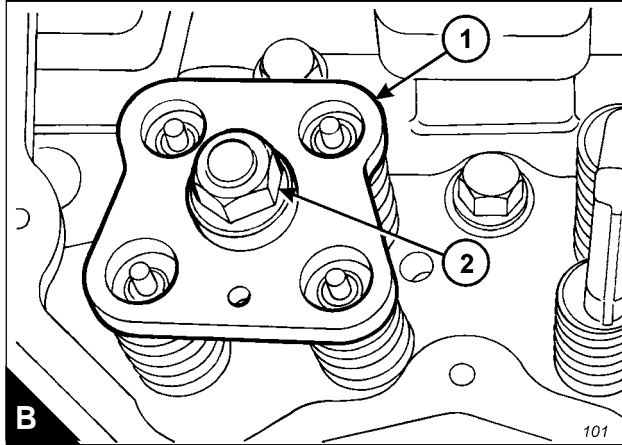
4 Use the valve spring compressor, GE50026, to compress the valve springs.

5 Fit the collets (A1) to each valve.

**Caution:** The collets can move during the installation. Ensure that the collets are seated correctly during this procedure.

*Continued*

- 6 Loosen slowly and then remove the nut (B2) and plate (B1) of the valve spring compressor. Remove the other parts of the valve spring compressor tool and ensure that the collets are fitted correctly to the valve stems.
- 7 Ensure that the collets are seated correctly. With the use of a soft hammer hit the top of the valve to help install the collets into position.
- 8 Fit the electronic fuel unit injectors, see Operation 11-1.
- 9 Fit the rocker lever and rocker shaft assemblies, see Operation 3-3.



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**Valves**

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**To remove and to fit**

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**Operation 3-8**

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**Special requirements**

Special tools	
Description	Part number
Valve spring compressor	GE50026

**To remove**

1 Remove the cylinder head, see Operation 3-6.

**Note:** If more than one valve is to be removed, make a note of the position of the valves as they are removed from the cylinder head.

2 Position the cylinder head, flame face down, on a bench with a soft surface and release the valves by use of the valve spring compressor GE50026, see Operation 3-7.

3 Remove the valve stem seal, see Operation 3-8.

4 Remove the valves from the cylinder head.

5 Repeat the procedure for all valves which are to be removed.

**To fit**

1 Apply clean engine lubricating oil to the stems of the valves. Fit the valves to their original positions in the cylinder head.

2 Fit the valve stem seal, see Operation 3-8.

3 Use the special tool GE50026 in order to install the valve springs, see Operation 3-7.

4 Fit the cylinder head, see Operation 3-6.



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**Valve seals**

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To renew

**Operation 3-9**

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**Special requirements**

Special tools	
Description	Part number
Insertion tool, valve seal	GE50027

**Note:** The valve seals can be removed with the cylinder head either fitted to or removed from the engine.

- 1 Remove the relevant valve spring assembly, see Operation 3-7.
- 2 Remove the valve seal from the valve and valve guide.
- 3 Apply a thin film of clean engine lubricating oil to the new valve seal and slide the seal over the valve stem.
- 4 If the valve seal is to be fitted to a valve guide with the valve removed, fit the seal to the special tool, GE50027. Insert the seal pin (part of the special tool GE50027) through the insertion tool, then enter the seal pin into the bore of the valve guide.
- 5 Use the special tool GE50027 and hand pressure only to push the valve seal into its position in the valve guide.
- 6 Remove the tool and fit the valve spring assembly, see Operation 3-7.

## Valve guides

To remove and to fit

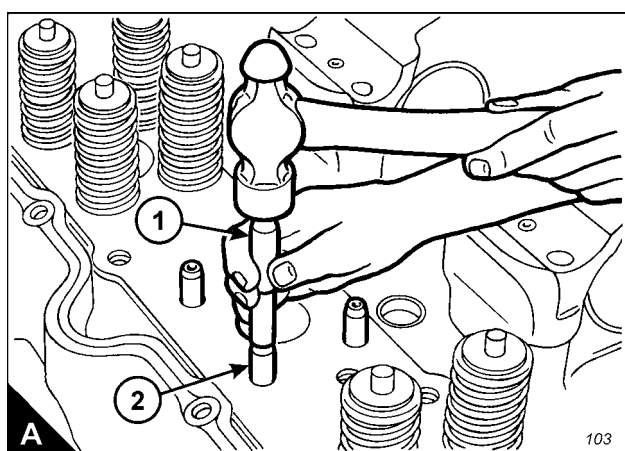
**Operation 3-10**

### Special requirements

Special tools	
Description	Part number
Removal/installation tool	GE50043
Sleeve	GE50044

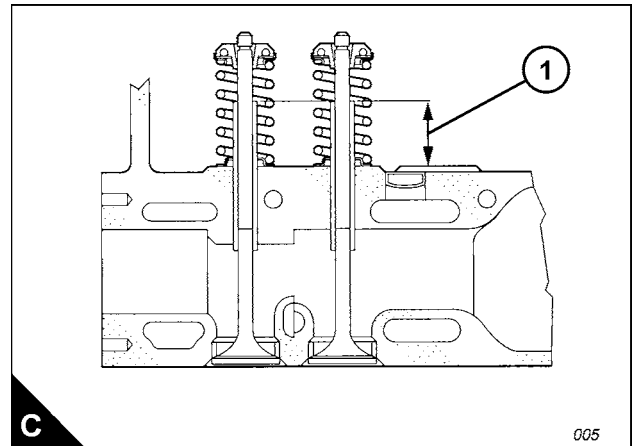
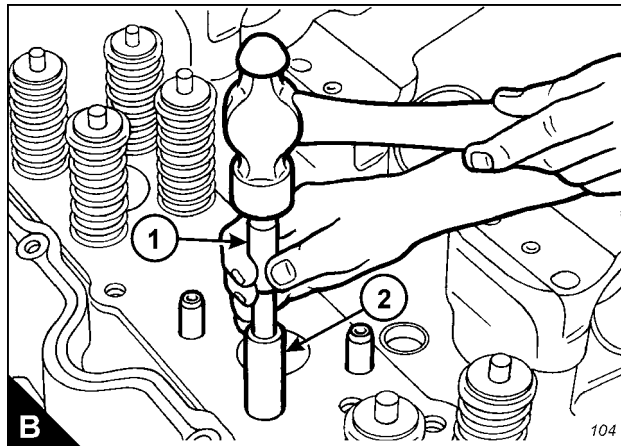
### To remove

- 1 Remove the cylinder head, see Operation 3-6.
- 2 Remove the valves, see Operation 3-8.
- 3 Use the special tool (A1) GE50043 and a hammer to drive the valve guide (A2) from the cylinder head.



**To fit**

- 1 Apply clean engine lubricating oil to the outside diameter of the new valve guides.
- 2 Use the special tool (B1), GE50043, together with the sleeve (B2) GE50044 in order to install the valve guide. The guide must protrude from the cylinder head, as shown (C1), by  $35,0 \pm 0,5$  mm ( $1.38 \pm 0.02$  in). Refer to Chapter 2, Specifications for the correct dimensions for the inside diameter of new and used valve guides.
- 3 When a new valve guide has been fitted, check that there is full contact between the valve and the valve seat. If necessary, lap the valve to the seat.
- 4 Fit the valves, see Operation 3-8.
- 5 Fit the cylinder head, see Operation 3-6.



## Camshaft

To remove and to fit

## Operation 3-11

## Special requirements

Special tools		Consumable products	
Description	Part number	Description	Part number
Engine turning tool	CH11148	POWEPART Threadlock and nutlock (10 ml)	
Guide stud	GE50019		
Cradle tool	GE50018		
Camshaft guide	GE50017		21820 117
Two Pilots	GE50015		
Lifting hooks	GE50025		
Alignment sleeve	GE50016		

## To remove

- 1 Remove the radiator, see Operation 12-4.
- 2 Remove the fan, see Operation 12-5.
- 3 Remove the gear case cover, see Operation 6-1.
- 4 Remove the rocker cover, see Operation 3-1.
- 5 Set the engine to TDC on compression stroke, see Operation 8-1.
- 6 Remove the rocker lever and shaft assemblies, see Operation 3-3.

**Cautions:**

- If the flywheel is turned past the threaded hole, the flywheel must be turned in the opposite direction for approximately 45 degrees and then back in the normal direction of rotation until the timing setscrew engages with the threaded hole. This is to eliminate backlash.
- Do not rotate the crankshaft with the camshaft gear or any of the idler gears removed and the rocker shaft assemblies installed. Damage can be caused to the pistons and valves, or to both.

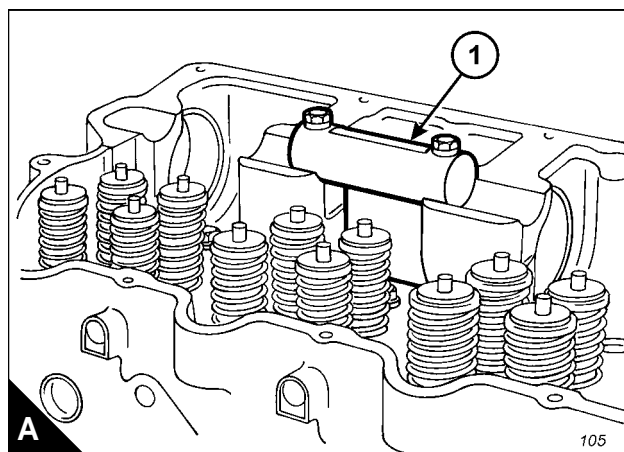
- 7 Disconnect the electrical connection to the camshaft timing sensor from behind the top of the gear case.

**Note:** Use suitable lift equipment in order to remove the camshaft gear.

- 8 Remove the camshaft gear, see Operation 6-2.

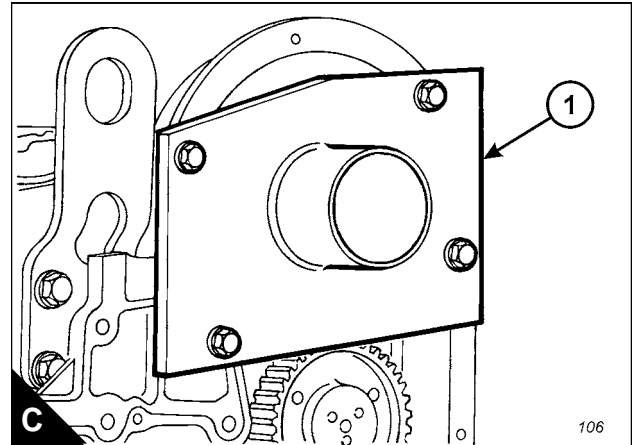
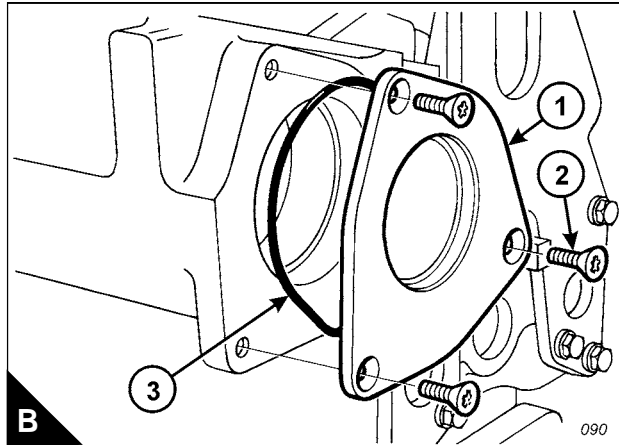
**Note:** Take care during removal of the camshaft to ensure that the surfaces of both the camshaft and the camshaft bearings are not damaged. Use the procedure which follows, together with the relevant special tools, to avoid damage to the engine and components.

- 9 Use the setscrews of the rocker shaft to retain the cradle tool (A1) GE50018 at the position shown (A).



Continued

10 Remove the rear cover (B1), complete with seal (B3).



11 Fit the camshaft guide (C1) GE50017 to the gear case. Do not tighten the setscrews for the guide at this stage.

**Note:** It is necessary to install the two pilots GE50015 on the rear end of the camshaft. The second pilot will support the rear of the camshaft as it is moved from the cylinder head and into the guide GE50017.

12 Install a pilot tool GE50015 into the threaded hole at the rear end of the camshaft. Then attach the second pilot tool GE50015 to the first pilot tool.

13 Remove the camshaft until it enters the bore of the camshaft guide. Tighten the setscrews which retain the guide on the gear case.

14 Use the lifting hooks GE50025 to move the camshaft toward the front of the engine.

**Caution:** During use of the lifting hooks do not raise the camshaft; the camshaft should be supported by the cradle GE50018. If the camshaft is raised, damage to the camshaft bearings can occur.

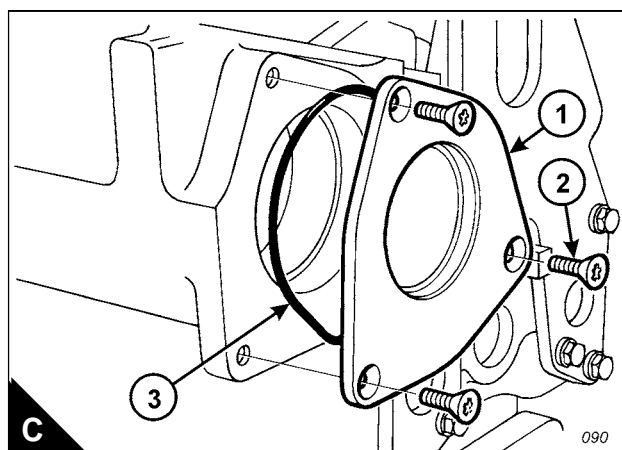
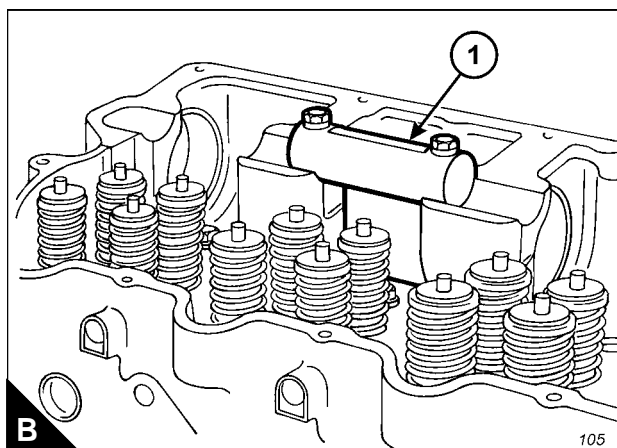
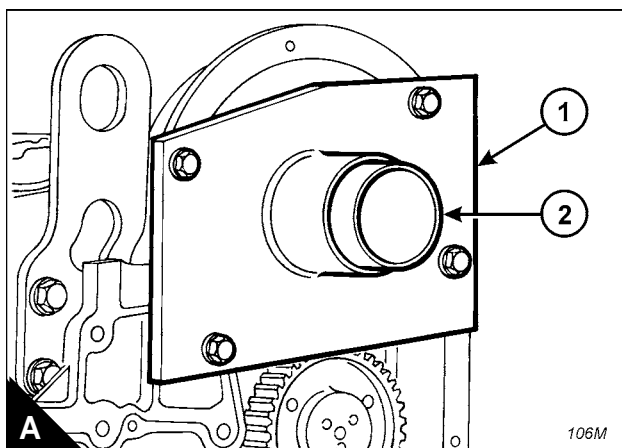
15 Remove the camshaft from the cylinder head just enough for a strap and hoist to be attached. Use suitable lift equipment in order to support the camshaft, ensure that the camshaft is kept level and remove it from the cylinder head. The camshaft weighs approximately 39 kg (85 lb).

**To fit**

- 1 Fit the two pilot tools GE50015 to the rear end of the camshaft. Ensure that the camshaft and camshaft bearings have been cleaned thoroughly. Apply clean engine lubricating oil to the lobes and journals of the camshaft. Apply a thin coat of clean engine lubricating oil to the camshaft bearings.
- 2 Fit the camshaft guide (A1) GE50017 to the gear case cover, but do not tighten the setscrews fully.
- 3 Insert the alignment sleeve (A2) GE50016 through the camshaft guide (A1) and into the camshaft bearings in order to align the camshaft guide correctly. Tighten the setscrews which retain the camshaft guide GE50017 on the gear case. Remove the alignment sleeve; the sleeve should move freely from the bore of the camshaft guide GE50017.
- 4 Fit the cradle tool (B1) GE50018 at the position shown (B).

**Notes:**

- Rotate the camshaft in both directions during installation to prevent binding.
  - Use suitable lift equipment in order to support the camshaft.
- 5 Insert the camshaft through the guide and into the cylinder head. Move the camshaft into the head as far as the lift equipment will allow.
  - 6 Remove the lift equipment. Rotate the camshaft during installation. Do not allow the end of the camshaft to drop during removal of the lift equipment as the bearings can be damaged. Use the lifting hooks GE50025 to support the camshaft during installation.
  - 7 Remove the pilot tools and push the camshaft fully into its bore.
  - 8 Inspect the seal (C3) and renew if necessary. Fit the rear cover (C1), complete with seal (C3).

*Continued*

**9** Remove the cradle tool and the camshaft guide.

**Note:** Camshaft timing is very important. During installation of the camshaft assembly, ensure that the timing marks on the camshaft gear and the gear case cover are aligned when number one cylinder is at top dead centre (TDC), see Operation 8-1.

**10** Fit the camshaft timing sensor behind the top of the gear case and connect the lead.

**11** Fit the camshaft gear, see Operation 6-3.

**Note:** Ensure that the camshaft is timed correctly to the crankshaft.

**12** Check the camshaft gear back lash, see Operation 6-6.

**13** Install the rocker lever and shaft assemblies, see Operation 3-3.

**14** Fit the gear case cover, see Operation 6-1.

**15** Fit the fan, see Operation 12-5.

**16** Fit the radiator, see Operation 12-4.

## Fuel injector sleeves

To remove and to fit

### Operation 3-12

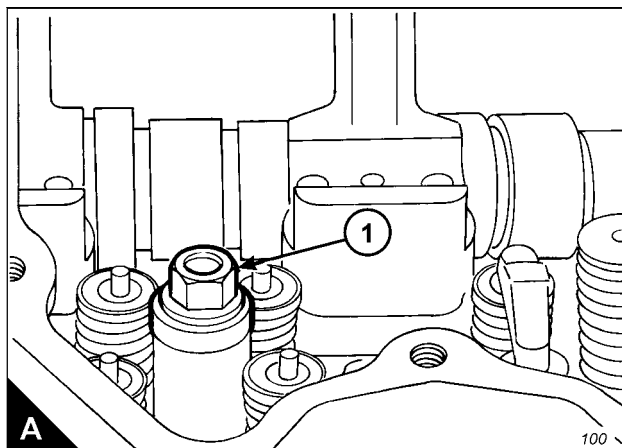
#### Special requirements

Special tools			
Description	Part number	Description	Part number
Injector installer/removal	GE50021	Brush	GE50022
Vacuum pump	GE50028	Brush	GE50023
Tube	GE50030	Brush	GE50024
Bottle	GE50029		

Consumable products	
Description	Part number
Retaining compound	CV60893

#### To remove

- 1 Drain the cooling system to below the level of the cylinder head. Refer to the User's Handbook TPD1516.
- 2 Remove the rocker shaft assemblies, see Operation 3-3.
- 3 Remove the electronic fuel injector units, see Operation 11-1.
- 4 Mark the bridge pieces and make a note of their position to assist during assembly, then remove the bridge pieces.
- 5 Fit the puller stud from the special tool GE50021 into the fuel injector sleeve as shown (A). Fit the bridge, thrust bearing, washer and nut, from the special tool, over the stud as shown. Tighten the nut (A1) of the special tool until the sleeve is drawn from the cylinder head. Remove the special tool from the sleeve.
- 6 Remove the 'O' ring seals from the fuel injector sleeve. Check the condition of the fuel injector sleeve and renew if necessary.
- 7 Repeat steps 1 to 5 for the fuel injector sleeves which remain.





**To fit**

**Caution:** Before installation ensure that the fuel injector sleeve and its bore in the cylinder head are clean and free from oil, dirt and sealant.

1 Use the brushes, special tool numbers: GE50023, GE50024 and GE50022, to clean thoroughly the bore for the fuel injector sleeve.

**Caution:** Ensure that the fuel passage in the cylinder head is clean.

2 Fit new 'O' ring seals to the fuel injector sleeve.

3 Fit the stud from the special tool into the threads of the fuel injector sleeve.

**Caution:** Do not apply retaining and anti-seize compounds to the cylinder head surfaces. These compounds must only be applied to the fuel injector sleeve.

4 Apply CV60889 anti-seize compound to the 'O' ring seals and to the large diameter (B1) off the fuel injector sleeve.

5 Apply CV60893 retaining compound to the small diameter (B2) off the fuel injector sleeve.

6 Use the stud in order to insert the fuel injector sleeve into its bore in the cylinder head. Take care to prevent damage to the 'O' ring seals. Only use hand force in order to push the fuel injector sleeve into the cylinder head.

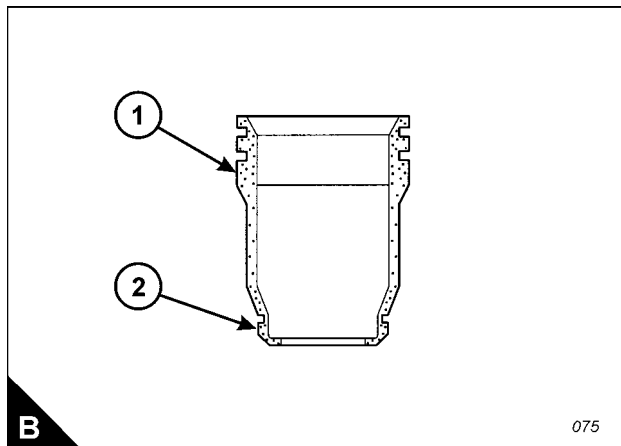
7 Fit the driver tool over the stud. Lightly hit the drive tool with a hammer to ensure that the fuel injector sleeve is fully seated in the cylinder head. The tool and sleeve will "ring" when the sleeve is in full contact with the base of the bore.

8 Use a clean cloth to remove any retaining or anti-seize compound from the bores of the cylinder and fuel injector sleeve.

9 Fit the electronic fuel injector units, Operation 11-1.

10 Fit the rocker shaft assemblies, Operation 3-3.

11 Fill the cooling system.



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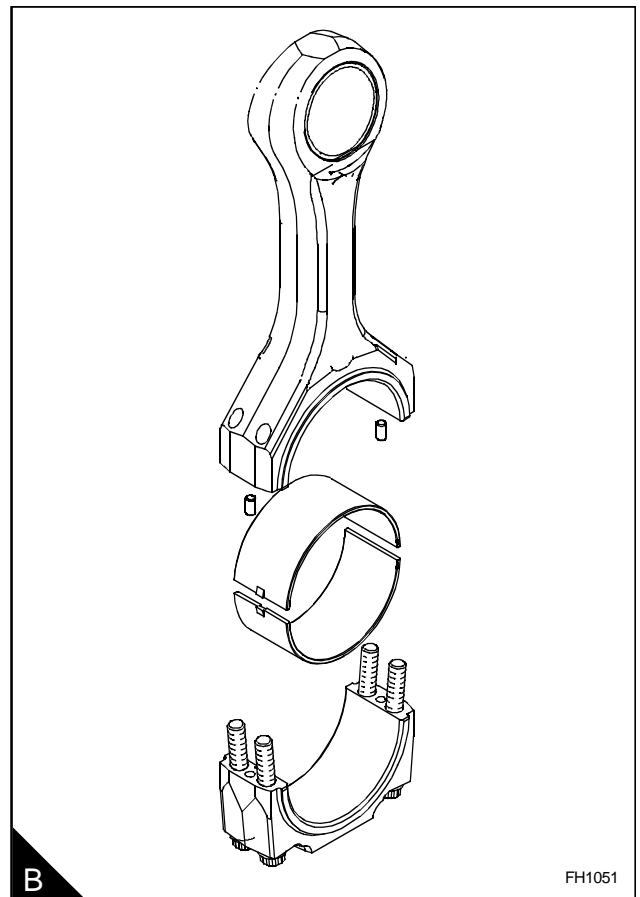
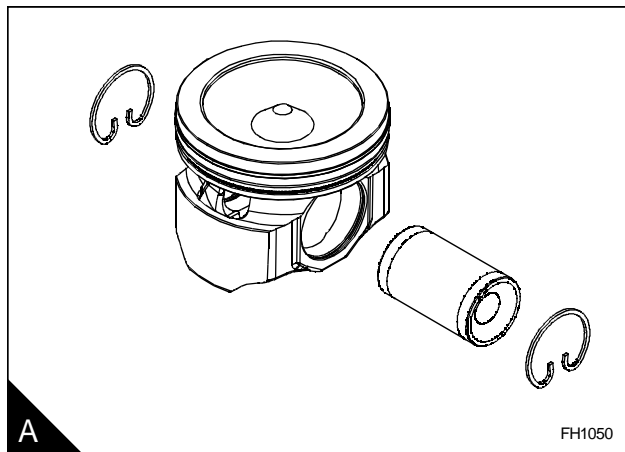
# 4

## Pistons and connecting rod assemblies

### General information

The piston (A) fitted to the 2806-18 litre engine is a one piece unit. The piston is held by the gudgeon pin connected to the connecting rod (B). The pistons each have three rings. The top ring is keystone shaped and its face is plasma coated. The second ring has a tapered face which has a chrome finish. The third ring is an oil control ring and also has a chrome finish on its face. The oil control ring contains a coil spring which expands the ring. Small holes in the piston groove allow oil from the oil control ring to drain back to the sump.

The connecting rods are of a conventional design. The small end is wedge shaped and the big end bearing cap is retained by four special setscrews. A split type shell bearing is fitted at the big end and a single piece bearing is pressed into the small end.



## Pistons and connecting rod

To remove and to fit

Operation 4-1

### Special requirements

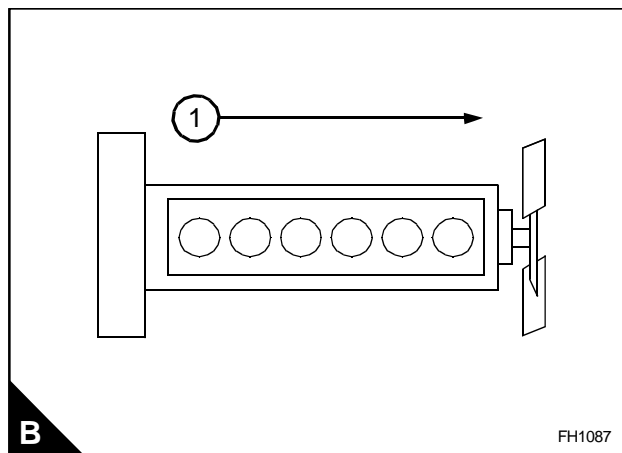
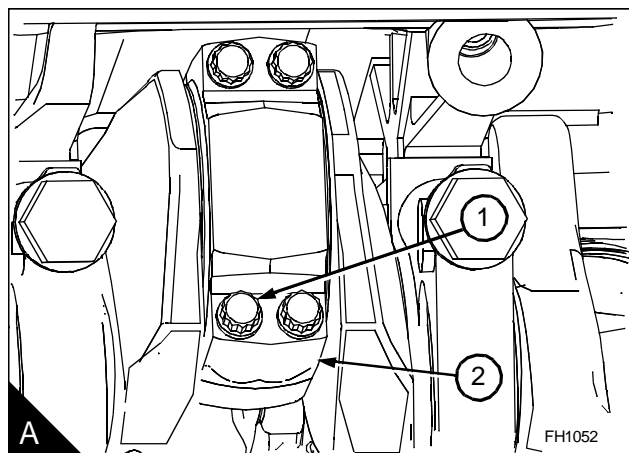
Special tools		Consumable products	
Description	Part number	Description	Part number
Installer, piston	GE50003	Anti-seize compound	CV60890

### To remove

- 1 Remove the cylinder head assembly, see Operation 3-6.
- 2 Remove the sump and plate, see Operation 10-5.
- 3 Remove the lubricating oil pump, see Operation 10-6.
- 4 Remove the carbon ridge from the top inside surface of the cylinder liners.
- 5 Rotate the crankshaft until two pistons are at bottom centre.

### Notes:

- Ensure that the connecting rod and piston is marked to show the cylinder number.
  - If the piston is to be removed from the connecting rod the piston must be marked to show the front of the engine (B1) in order to help in assembly.
- 6 Remove the setscrews (A1) and the bearing cap (A2). Push the connecting rod and piston up until the rings are free from the cylinder liner.
  - 7 Carefully remove the piston and connecting rod from the cylinder liner. Keep the bearing caps with their relevant connecting rods.
  - 8 Repeat steps 3 to 6 for the remainder of the pistons and connecting rods.



**To fit**

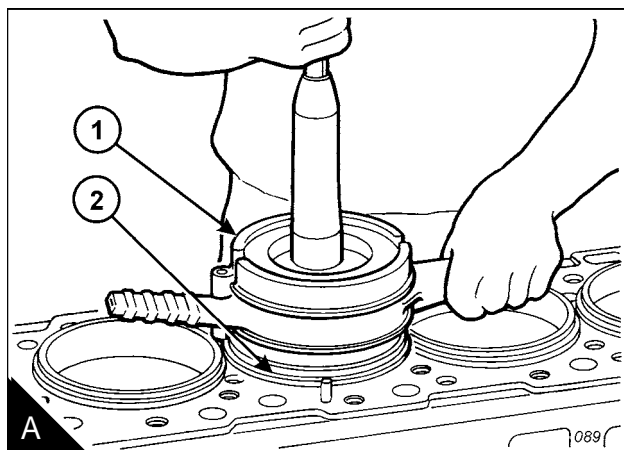
- 1 Apply clean engine lubricating oil to the piston rings, the connecting rod bearings and the cylinder liners.
- 2 Ensure that the piston ring gaps are set at 120 degree apart.
- 3 Use the special tool GE50003 (A1) to install the piston and the connecting rod in the cylinder liner (A2). Ensure that the piston rings are not damaged during the operation.

**Cautions:**

- *The connecting rod must be fitted with tab groove side of the big end bearing at the opposite side to the camshaft.*
- *Bearing caps must be fitted to their original connecting rods.*

**Note:** The cap must be fitted with its number on the same side as that on the connecting rod and the number must be the same.

- 4 Apply anti-seize compound CV60890 to the setscrew threads. Install the setscrews and bearing cap. Tighten each setscrew in the bearing cap to a torque of 90 Nm (66 lbf ft) 9,1 kgf m. Make a temporary mark on each setscrew and the bearing cap, then tighten each setscrew by an additional 90 degrees.
- 5 Repeat steps 1 to 4 for the remainder of the pistons and connecting rods.
- 6 Fit the oil pump, Operation 10-6.
- 7 Fit the plate and sump Operation 10-5.
- 8 Fit the cylinder head assembly, Operation 3-6.



## To dismantle and assemble

## Operation 4-2

## To dismantle

1 Remove the pistons and connecting rod assemblies, see Operation 4-1.

**Note:** Mark the alignment of the piston to the connecting.

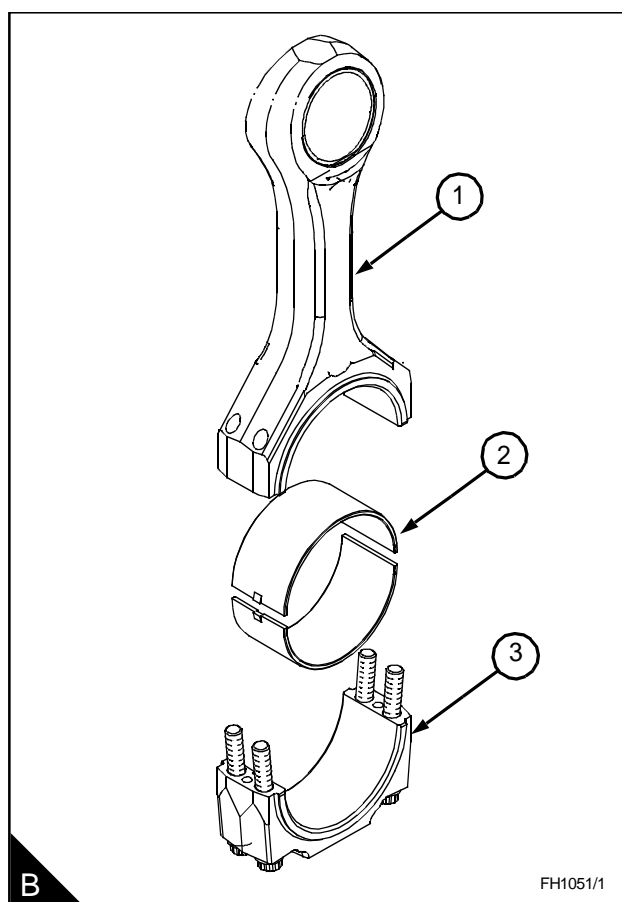
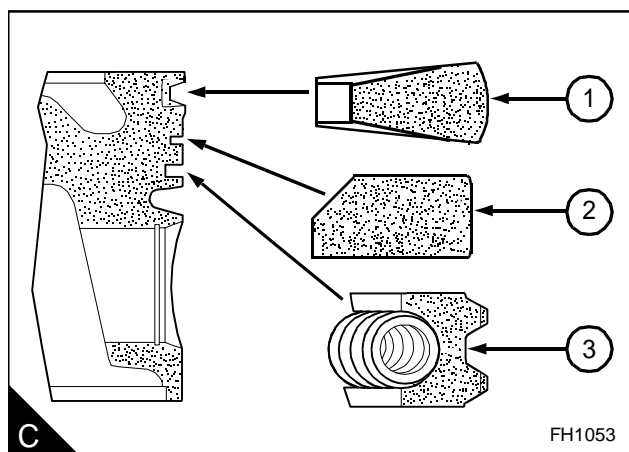
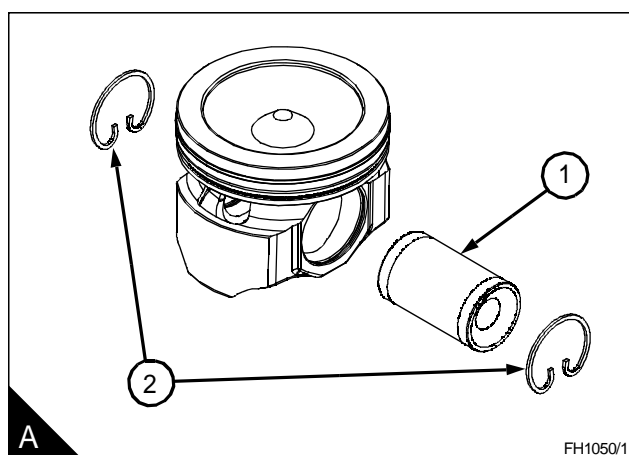
2 Remove the big-end bearing shells (B2) from the connecting rod (B1) and connecting rod cap (B3). If the bearings shells are to be used again, make a note of the position where they were fitted.

3 Remove the circlips (A2).

4 Remove the gudgeon pin (A1) and separate the connecting rod (B1) from the piston.

5 Carefully remove the top piston ring (C1) the second piston ring (C2) and the oil control ring (C3). Clean the piston ring grooves with a suitable cleaning tool.

**Note:** Special equipment is required to renew the small end bearing. If this operation becomes necessary, contact your Perkins dealer/distributor.



**To assemble**

**1** Check the gaps between the ends of the piston rings when the rings are inserted in a new liner. The rings can also be checked by insertion in an unworn part of a used liner.

For the correct dimensions refer to Chapter 2, Specifications.

**2** Fit the spring (A1) of the oil control ring to its groove in the piston.

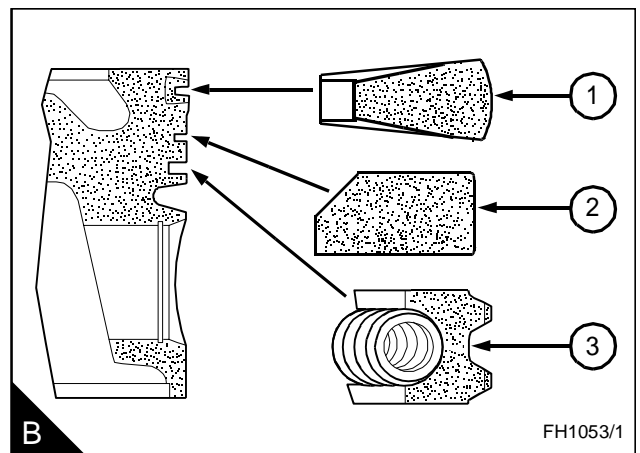
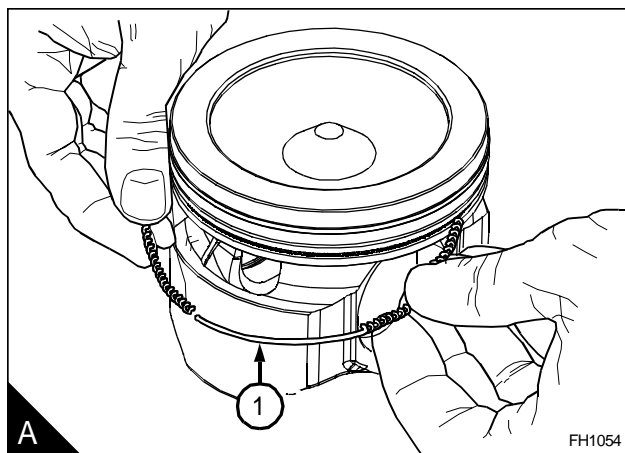
**Note:** The oil control ring must be fitted over the spring with the gap of the oil control ring at 180 degrees from the joint of the spring.

**3** Use a suitable piston ring expander to fit the oil control ring (B3) to its groove in the piston crown.

**4** Fit the second piston ring (B2) with the side that has the identification "UP-2" toward the top of the piston. Use a suitable piston ring expander.

**5** Fit the top piston ring (B1) with the side that has the identification "UP-1" toward the top of the piston. Use a suitable piston ring expander.

**6** When all three piston rings have been fitted, adjust the position of the piston ring gaps so that they are 120 degrees apart.

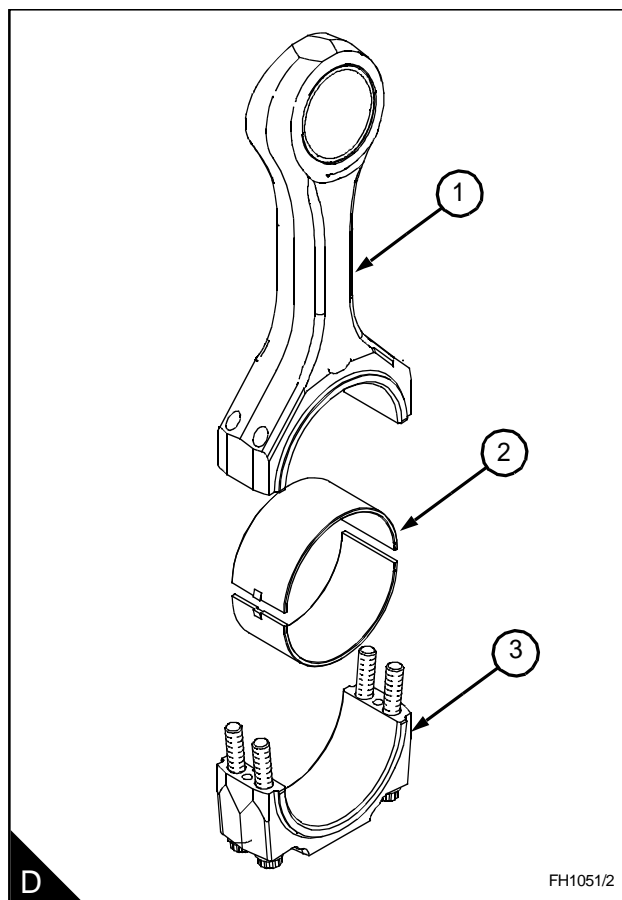
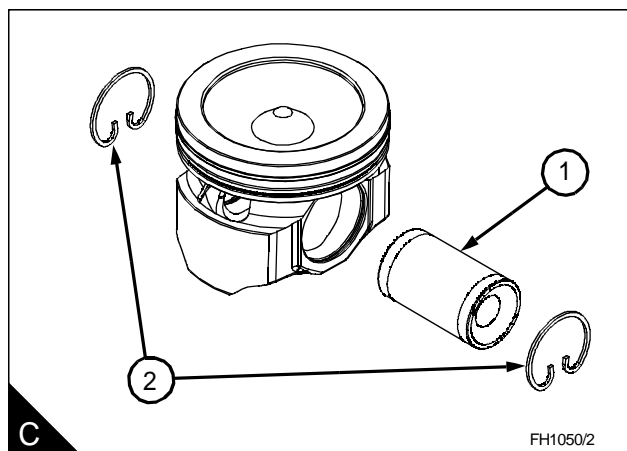


*Continued*

7 Apply clean engine lubricating oil to the gudgeon pin (C1) and install the pin into the piston and connecting rod (D1). Fit the circlips (C2). Ensure that the circlips are fully in the grooves of the piston.

**Note:** Ensure that the piston is aligned correctly to the connecting rod.

8 Fit the big-end bearing shells (D2) to the connecting rod (D1) and connecting rod cap (D3). If the original bearings are to be used, ensure that they are fitted to their original positions.



**Note:** The tabs at the back of the bearing shells must be fitted correctly in the tab slots of the connecting rod and connecting rod cap.

9 Fit the pistons and connecting rod, see Operation 4-1.



## Piston cooling jets

To remove and to fit

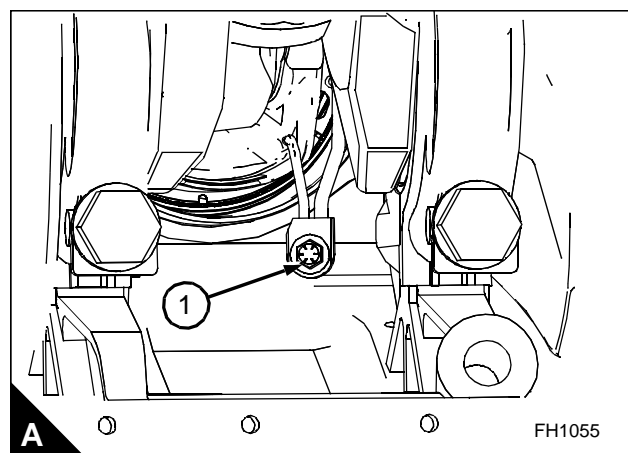
Operation 4-3

### Special requirements

Special tools	
Description	Part number
Engine turning tool	CH11148

### To remove

- 1 Remove lubricating oil pump, see Operation 10-6.
- 2 Use the engine turning tool CH11148 to turn the crankshaft in a clockwise direction (as seen from the front of the engine) to obtain access to the relevant piston cooling jet.
- 3 Remove the setscrew (A1) which retains the cooling jet and remove the cooling jet from the engine.



- 4 Repeat steps 2 and 3 for the cooling jets which remain.

### To fit

- 1 Carefully fit the piston cooling jets to the engine, ensure that the nozzles of the cooling jets are not damaged or distorted during the operation.
- 2 Tighten the setscrew (A1) to 40 Nm (30 lbf ft) 4 kgf m.
- 3 Turn the crankshaft clockwise (as seen from the front of the engine) as necessary to obtain access to the relevant positions.
- 4 Fit the lubricating oil pump, see Operation 10-6.

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# 5

## Crankshaft assembly

### General information

**Warning!** Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

The crankshaft fitted to the 2800 Series engines has 13 bearing surfaces, which consists of seven main journals and six crank pins. Each crank pin holds two connecting rods.

Eight counterweights are included within the crankshaft forging and a vibration damper is fitted at the front end to reduce torsional vibrations.

A gear at the front end of the crankshaft provides the drive for the engine timing gears, the coolant pump and the lubricating oil pump.

To seal the crankcase, crankshaft seals are fitted in the gear case and the flywheel housing.

## Crankshaft

To remove and to fit

**Operation 5-1**

### Special requirements

Consumable products	
Description	Part number
Anti-seize compound	CV60890

### To remove

- 1 Remove the gear case cover, see Operation 6-1.
- 2 Remove the flywheel housing, see Operation 13-2.
- 3 Remove the pistons and connecting rod assemblies, see Operation 4-1.
- 4 Remove the crankshaft rear seal and wear sleeve, see Operation 5-3.
- 5 Remove the crankshaft front seal and wear sleeve, see Operation 5-2.

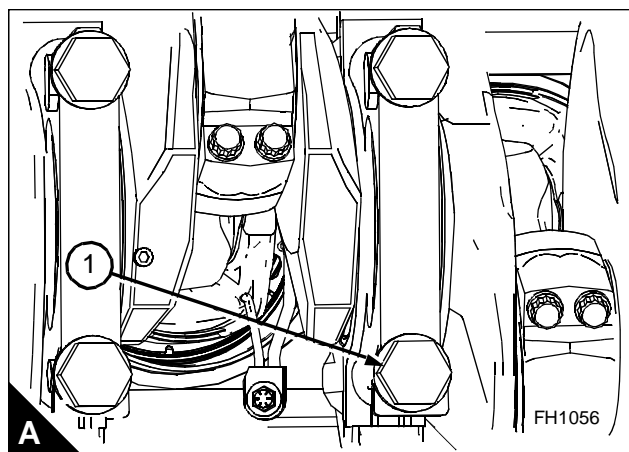
**Note:** Ensure that the bearing caps are marked in the correct position.

- 6 Remove the setscrews (A1) which retain the main bearing caps in the crankcase and remove the bearing caps.

- 7 Fit one of the setscrews from the front pulley to each end of the crankshaft.

### Notes:

- Use suitable lift equipment in order to lift the crankshaft from the crankcase. The weight of the crankshaft is approximately 159 kg (350 lb).
- If new main bearings are not to be installed, make a note of the position of the used bearings. Used bearings must be fitted to their original positions.



**To fit**

- 1** Clean the crankcase and the main bearing caps thoroughly. Apply clean engine lubricating oil to the main bearings and fit the upper halves of the main bearings into the crankcase.
- 2** Install one of the setscrews from the front pulley in each end of the crankshaft. Use suitable lift equipment in order to lift the crankshaft into the crankcase. Ensure that the line mark on the crankshaft gear is in alignment with the line on the idler gear.
- 3** Fit the thrust bearings for the centre main bearing. Ensure that the bearings are fitted with the side identification (block side) against the crankcase.
- 4** Fit the main bearings to the bearing caps.
- 5** Ensure that the tabs on the back of the bearing shells fit into the tab slots of the bearing caps and crankcase.  
**Caution:** *Ensure that the main bearing caps are fitted to the correct positions. The numbers on the side of the crankcase must be the same as the numbers on the bearing caps, and the arrows on the bearing caps must be directed toward the front of the crankcase.*
- 6** Apply anti-seize compound CV60890 to the setscrews and install the main bearing caps and setscrews.
- 7** Begin at the tab end of the bearing cap, tighten each bearing cap setscrew to a torque of 260 Nm (191 lbf ft) 26,5kgf m. Make a temporary mark on each setscrew and bearing cap. Start with the setscrew opposite the tab end of the bearing cap and again tighten each setscrew by an additional 120 degrees.
- 8** Use a dial test indicator (DTI) to check the end-float of the crankshaft. Ensure that the pointer of the DTI is against a machined surface. The end-float is controlled by the thrust bearings of the centre main bearing. The end-float with new bearings must be between 0,15 and 0,51 mm (0.006 and 0.020 in). The maximum permissible end-float with used bearings is 0,89 mm (0.035 in).
- 9** Fit the crankshaft front seal and wear sleeve, see Operation 5-2.
- 10** Fit the crankshaft rear seal and wear sleeve, see Operation 5-3.
- 11** Fit the pistons and connecting rod assemblies, see Operation 4-1.
- 12** Fit the flywheel housing, see Operation 13-2.
- 13** Fit the gear case cover, see Operation 6-1.

## Early type of crankshaft front seal and wear sleeve

To renew

Operation 5-2

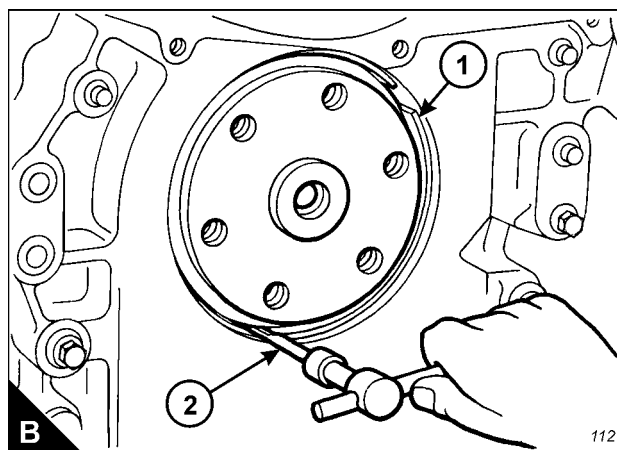
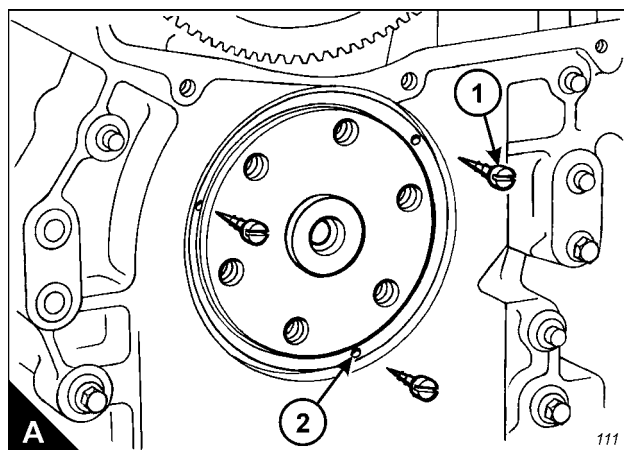
### Special requirements

Special tools		Consumable products	
Description	Part number	Description	Part number
Locator assembly	GE50008	Quick cure primer	CV60892
Bolt	GE50009		
Distorter protection ring	GE50010		
Distorter tool	GE50011	Retaining compound	CV60893
Installer	GE50012		
Nut	GE50014		

### To remove

**Caution:** The crankshaft front seal and wear sleeve are supplied as a assembly and must be installed as a assembly. If a seal is renewed, the wear sleeve must also be renewed.

- 1 Remove the vibration damper, see Operation 5-6.
- 2 Drill three holes (A2) at an equal distance around the circumference of the seal. Fit self-tapping screws (A1), complete with washers if necessary, into the holes and use a suitable tool as a lever to remove the seal from the crankcase. Ensure that the gear case does not become damaged during this operation.
- 3 Fit the distorter protection ring (B1) GE50010 to the seal bore and at the same depth as the wear sleeve. The distorter ring is fitted to protect the seal bore in the crankcase during the removal of the wear sleeve.
- 4 Insert the distorter tool (B2) GE50011 between the protection ring and the wear sleeve. With the sharp edge of the tool against the wear sleeve, use a socket and spanner to rotate the distorter and cause a crease to form in the wear sleeve. Repeat this procedure in three or more places until the wear sleeve becomes loose on the crankshaft.
- 5 Remove the distorter tool, the protection ring and the wear sleeve.



**To fit**

**Note:** Before the new seal and wear sleeve assembly is installed, read carefully the special instruction which is supplied with each seal and wear sleeve.

1 Clean the wear sleeve inside diameter and crankshaft outside diameter with quick cure primer, CV60892. Apply some retaining compound, CV60893, to the crankshaft outside diameter before the wear sleeve is installed on the crankshaft. Do not allow any quick cure primer or retaining compound to touch the lip of the seal.

2 Use the setscrews (A3) GE50009, to install the guide GE50008 on the crankshaft.

**Notes:**

- The seal and the wear sleeve assembly must be installed in a dry condition.
- Ensure that the seal is fitted with the part number and the crankshaft rotation arrows toward the outside.

**Cautions:**

- *The front and rear seals and wear sleeves have different spiral grooves. The seal will not function if it is installed at the wrong end of the engine.*
- *The seal must not be separated from the wear sleeve.*

3 Fit the wear sleeve and seal assembly (A4) as a unit onto the locator, GE50008.

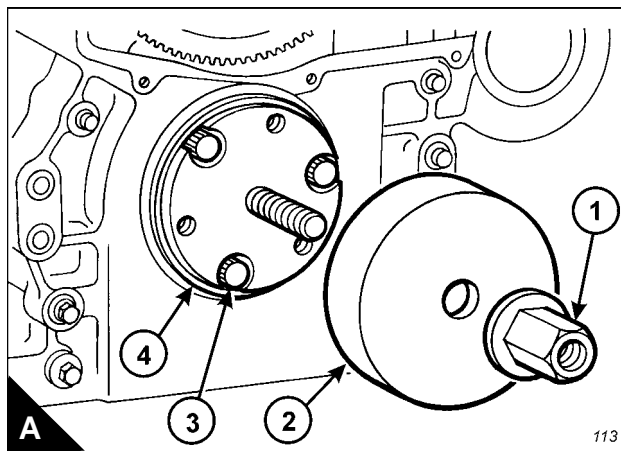
4 Fit the installer (A2) GE50012 onto the locator.

5 Apply clean engine lubricating oil to the face of the nut (A1) GE50014 and to its contact area on the installer, GE50012.

6 Fit the nut to the locator and tighten the nut until the inside surface of the installer is in contact with the locator.

7 Remove all of the tools from the crankshaft.

8 Fit the vibration damper, Operation 5-6.



## Early type of crankshaft rear seal and wear sleeve

To renew

Operation 5-3

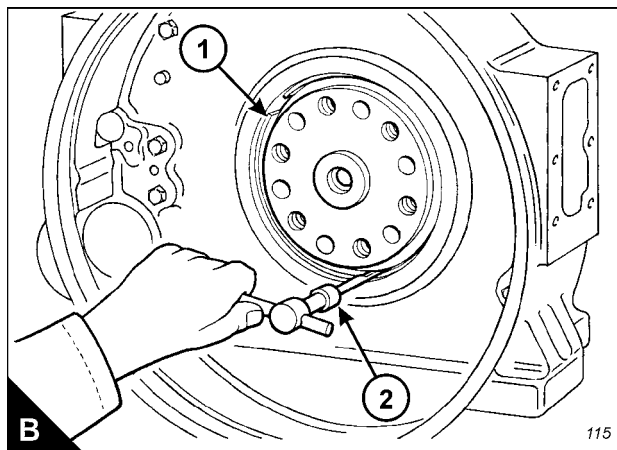
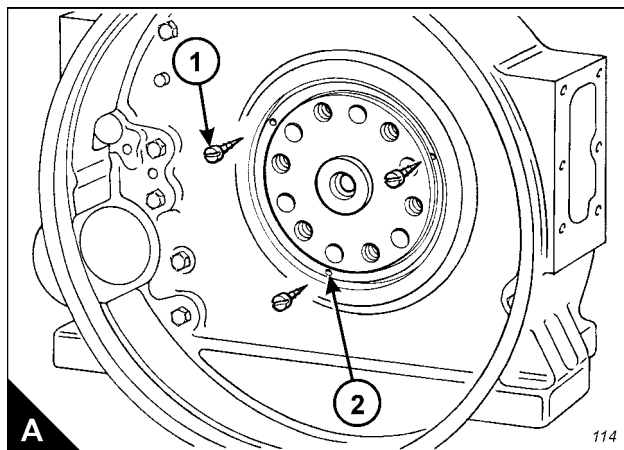
### Special requirements

Special tools		Consumable products	
Description	Part number	Description	Part number
Locator assembly	GE50008	Quick cure primer	CV60892
Bolt	GE50009		
Distorter protection ring	GE50010		
Distorter tool	GE50011	Retaining compound	CV60893
Installer	GE50013		
Nut	GE50014		

### To remove

**Caution:** The crankshaft front seal and wear sleeve are supplied as a assembly and must be installed as a assembly. If a seal is renewed, the wear sleeve must also be renewed.

- 1 Remove the flywheel, see Operation 13-1.
- 2 Drill three holes (A2) at an equal distance around the circumference of the seal. Fit self-tapping screws (A1), complete with washers if necessary, to the holes and use a suitable tool as a lever to remove the seal from the crankcase. Ensure that the flywheel housing does not become damaged during this operation.
- 3 Fit the distorter protection ring (B1) GE50010 to the seal bore and at the same depth as the wear sleeve. The distorter ring is fitted to protect the seal bore in the crankcase during the removal of the wear sleeve.
- 4 Insert the distorter tool (B2) GE50011 between the protection ring and the wear sleeve. With the sharp edge of the tool against the wear sleeve, use a socket and spanner to rotate the distorter and cause a crease to form in the wear sleeve. Repeat this procedure in three or more places until the wear sleeve becomes loose on the crankshaft.
- 5 Remove the distorter tool, the protection ring and the wear sleeve.





**To fit**

**Note:** Before the new seal and wear sleeve *assembly* is installed, read carefully the special instruction which is supplied with each seal and wear sleeve.

1 Clean the wear sleeve inside diameter and crankshaft outside diameter with quick cure primer, CV60892. Apply retaining compound CV60893 to the crankshaft outside diameter before the wear sleeve is installed on the crankshaft. Do not allow any quick cure primer or retaining compound to touch the lip of the seal.

2 Use the setscrews (C4) GE50009 to install the guide GE50008, on the crankshaft.

**Notes:**

- The seal and the wear sleeve assembly must be installed in a dry condition.
- Ensure that the seal is fitted with the part number and the crankshaft rotation arrows toward the outside.

**Cautions:**

- *The front and rear seals and wear sleeves have different spiral grooves. The seal will not function if it is installed at the wrong end of the engine.*
- *The seal must not be separated from the wear sleeve.*

3 Fit the wear sleeve and seal assembly (C3) as a unit onto the locator, GE50008.

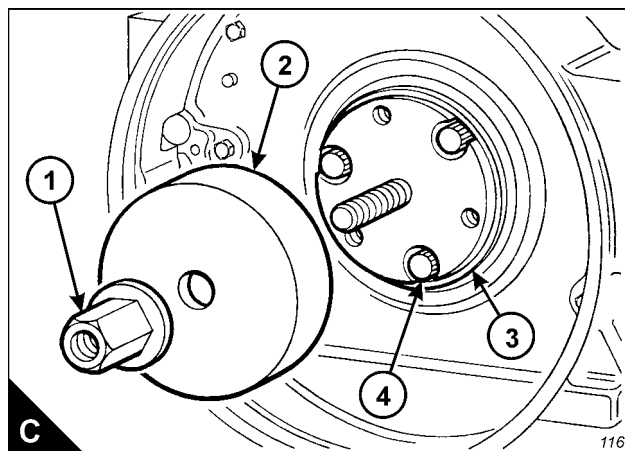
4 Fit the installer (C2) GE50012 onto the locator.

5 Apply clean engine lubricating oil to the face of the nut (C1) GE50014 and to its contact area on the installer GE50012.

6 Fit the nut to the locator and tighten the nut until the inside surface of the installer is in contact with the locator.

7 Remove all of the tools from the crankshaft.

8 Fit the flywheel, see Operation 13-1.



**New type of front crankshaft oil seal**

To remove and fit

**Operation 5-4****Special requirements**

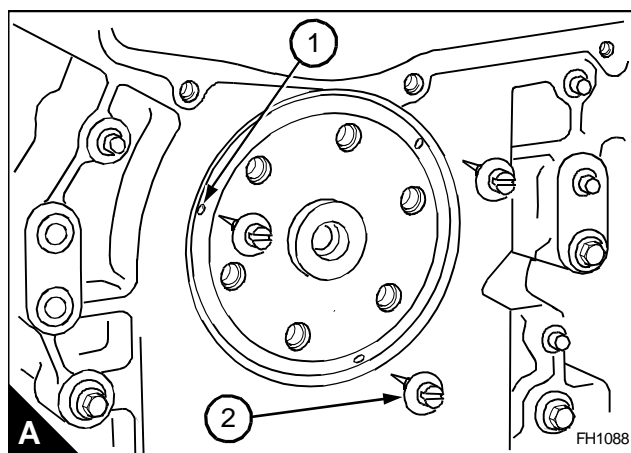
Special tools		
Description	Part number	Part number
Locator assembly	GE50008	CV60892
Bolt	GE50009	
Installer	GE50013	CV60893
Nut	GE50014	

**To remove**

- 1 Remove the vibration damper, see Operation 5-6.
- 2 Drill three holes (A1) at an equal distance around the circumference of the seal. Fit self-tapping screws, complete with washers (A2), into the holes and use a suitable tool as a lever to remove the seal from the crankcase.

**Notes:**

- Ensure that the gear case does not become damaged during this operation.
- As the seal is removed the wear sleeve will also be removed.



## To fit

**Note:** Before the new seal and wear sleeve are installed, read carefully the special instruction supplied.

**3** Ensure that the crankshaft is clean and dry.

**4** Fit the setscrews (A3) GE50009 in order to install the guide GE50008 on the crankshaft.

**Notes:**

- Do not apply any lubricate in order install the seal.
- Ensure that the seal is fitted with the part number and the crankshaft rotation arrows toward the outside.

**Caution:** The front and rear seals and wear sleeves have different spiral grooves. The seal will not function if it is installed at the wrong end of the engine.

**5** Fit the wear sleeve and seal assembly (A4) onto the locator, GE50008.

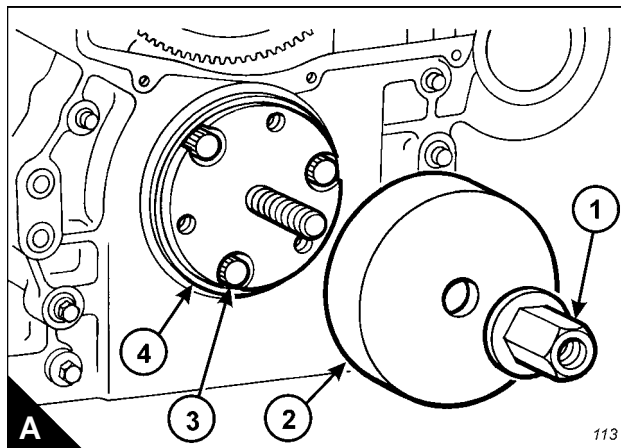
**6** Fit the installer (A2) GE50012 onto the locator.

**7** Apply clean engine lubricating oil to the face of the nut (A1), GE50014, and to its contact area on the installer GE50012.

**8** Fit the nut to the locator and tighten the nut until the inside surface of the installer is in contact with the locator.

**9** Remove all of the tools from the crankshaft.

**10** Fit the vibration damper, see Operation 5-6.



## New type of rear crankshaft oil seal

To remove and fit

**Operation 5-5**

**To remove**

**Special requirements**

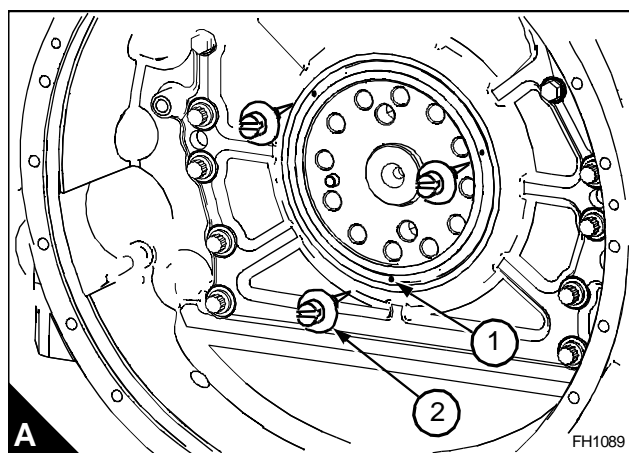
Special tools	
Description	Part number
Locator assembly	GE50008
Bolt	GE50009
Nut	GE50014
Installer	GE5001

**1** Remove the flywheel, see Operation 13-1.

**2** Drill three holes (A1) at an equal distance around the circumference of the seal. Fit self-tapping screws (A2), complete with washers to the holes and use a suitable tool in order to remove the seal from the flywheel housing.

**Notes:**

- Ensure that the flywheel housing does not become damaged during this operation.
- As the seal is removed the wear sleeve will also be removed.



**To fit**

**Note:** Before the new seal and wear sleeve are installed, read carefully the special instruction supplied.

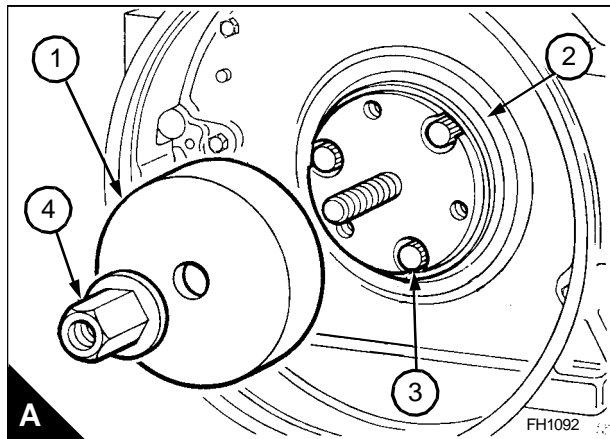
- 1 Ensure that the crankshaft is clean and dry.
- 2 Use the setscrews (A3) GE50009 to install the guide GE50008 on the crankshaft.

**Notes:**

- The seal and the wear sleeve must be installed in a dry condition.
- Ensure that the seal is fitted with the part number and the crankshaft rotation arrows toward the outside.

**Caution:** The front and rear seals and wear sleeves have different spiral grooves. The seal will not function if it is installed at the wrong end of the engine.

- 3 Fit the wear sleeve and seal assembly (A2) as a unit onto the locator, GE50008.
- 4 Fit the installer (A1) GE50012 onto the locator.
- 5 Apply clean engine lubricating oil to the face of the nut (A4) GE50014 and to its contact area on the installer GE50012.
- 6 Fit the nut to the locator and tighten the nut until the inside surface of the installer is in contact with the locator.
- 7 Remove all of the tools from the crankshaft.
- 8 Fit the flywheel, see Operation 13-1.



## Crankshaft vibration damper

To remove and to fit

### Operation 5-6

#### To remove

1 Remove the fan guards.

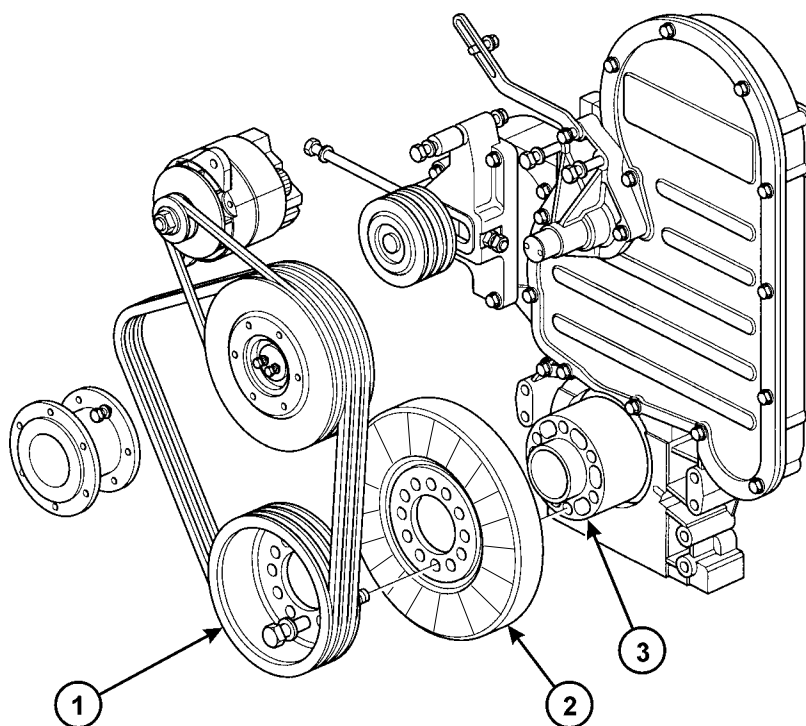
2 Remove the fan drive belts, see Operation 12-6.

**Note:** Use suitable lift equipment in order to remove the vibration damper (A2).

3 Remove the six setscrews and washers which retain the vibration damper and the adapter (A3) to the crankshaft.

4 Remove damper and adapter. The weight of the vibration damper is approximately 25 kg (55 lb).

**Note:** The dash marks at the front of the damper assembly must be in alignment with each other. If the dash marks are not in alignment, renew the damper assembly.



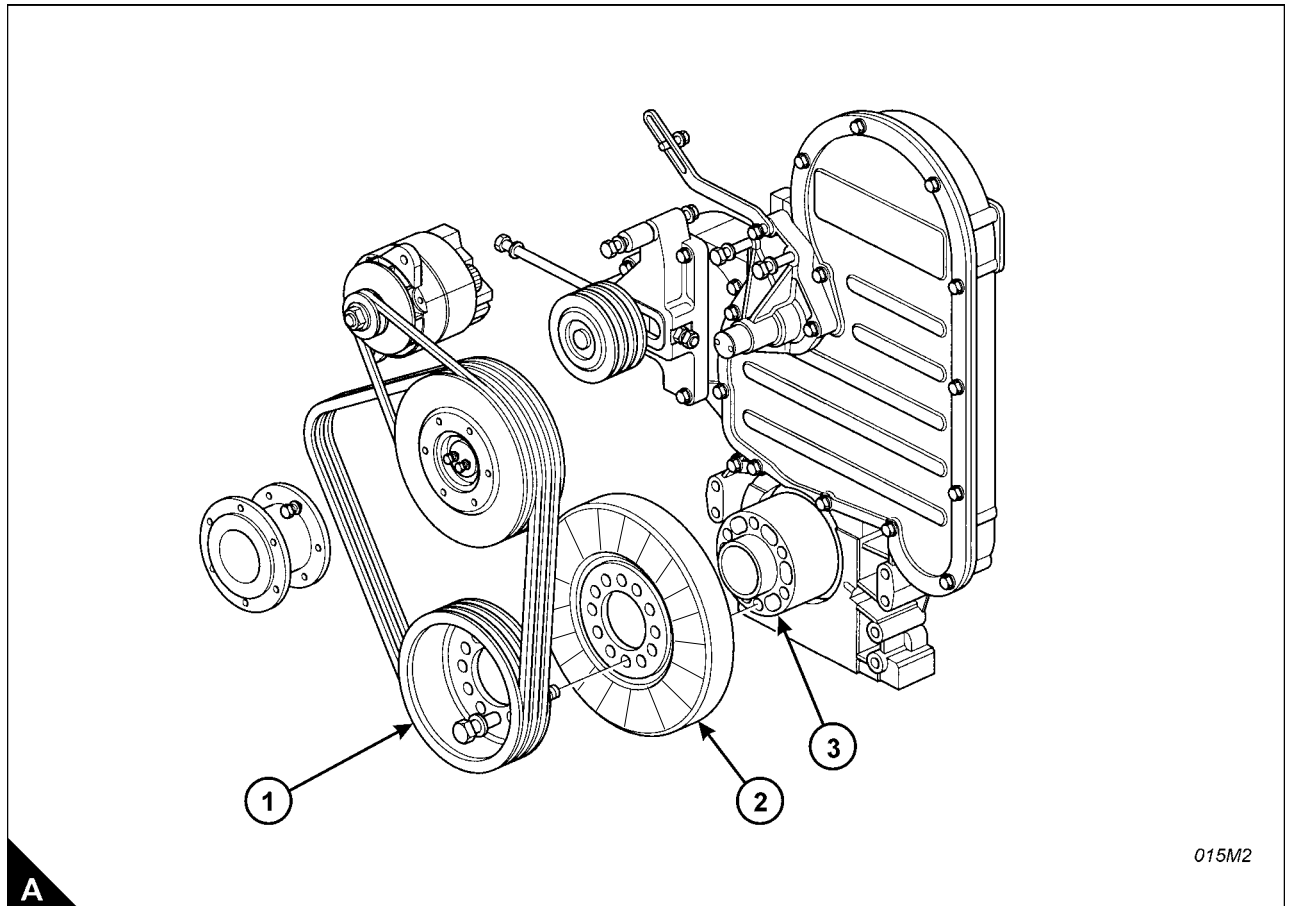
015M2

A

**To fit**

**Note:** Use suitable lift equipment in order to install the vibration damper (A2).

- 1 Use a 5/8 -18 x 6 in (152 mm) long guide stud, and fit the vibration damper (A2) and adapter (A3) to the crankshaft. The weight of the vibration damper is approximately 25 kg (55 lb).
- 2 Fit the crankshaft pulley (A1). Apply clean engine lubricating oil to the threads of the setscrews and install five of the six setscrews and washers which retain the pulley, the damper and the adapter.
- 3 Remove the guide stud and install the final setscrew and washer. Tighten the setscrews to a torque of 215 Nm (158 lbf ft) 21,9 kgf m.
- 4 Fit the fan belts and adjust the tension, see Operation 12-7.
- 5 Fit the fan guards.



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# 6

## Gear case and drive assembly

### General information

**Warning!** Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

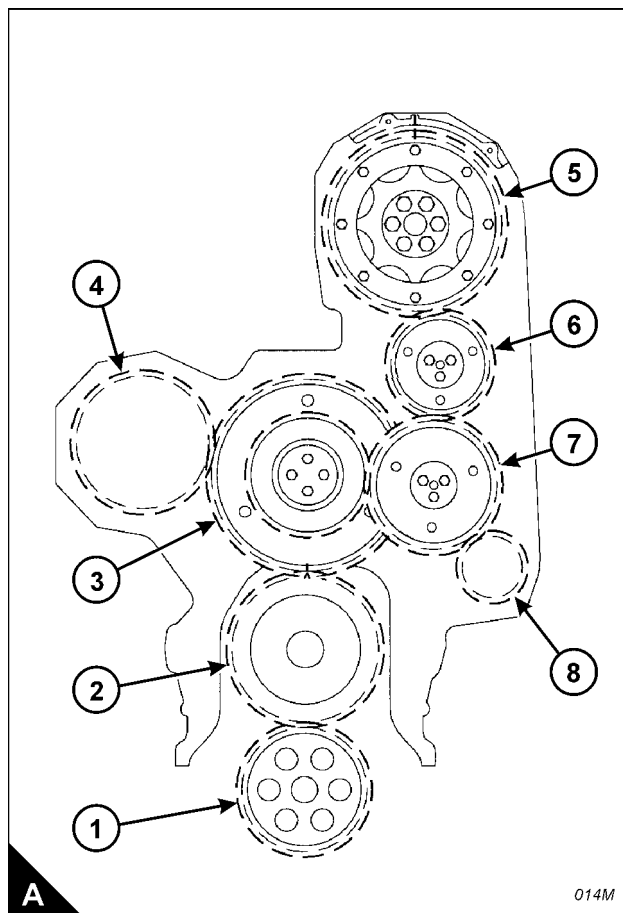
The cast iron gear case contains the timing gears for the engine and the gears which drive the coolant pump (A4), the lubricating oil pump (A1), also the fuel transfer pump (A8). All of the gears are spur gears.

An adjustable idler gear (A6) provides the backlash between the main idler (A7) and the camshaft gear (A5). If the cylinder head and head gasket are removed, the tolerances may change and the position of the adjustable idler gear can be adjusted to obtain the correct backlash settings.

The camshaft drive gear (A5) is fitted with pendulum rollers. These are designed to counteract the injector pulses and eliminate vibration and noise.

For correct engine timing, a line is provided on the large gear (A3) of the compound idler which aligns with a 'V' on the crankshaft gear (A2), and a mark on the camshaft drive gear aligns with a line at the top of the gear case.

**Caution:** Some setscrews used on the axles of the gears are a special locking setscrew. These setscrews use a material similar to nylon in order to lock the setscrew. Perkins Engine Company Limited recommend that these setscrews are discarded after use. If the setscrews are used again they must have POWERPART Threadlock and nutlock 21820117 applied to the threads.



## Gear case cover

To remove and to fit

### Operation 6-1

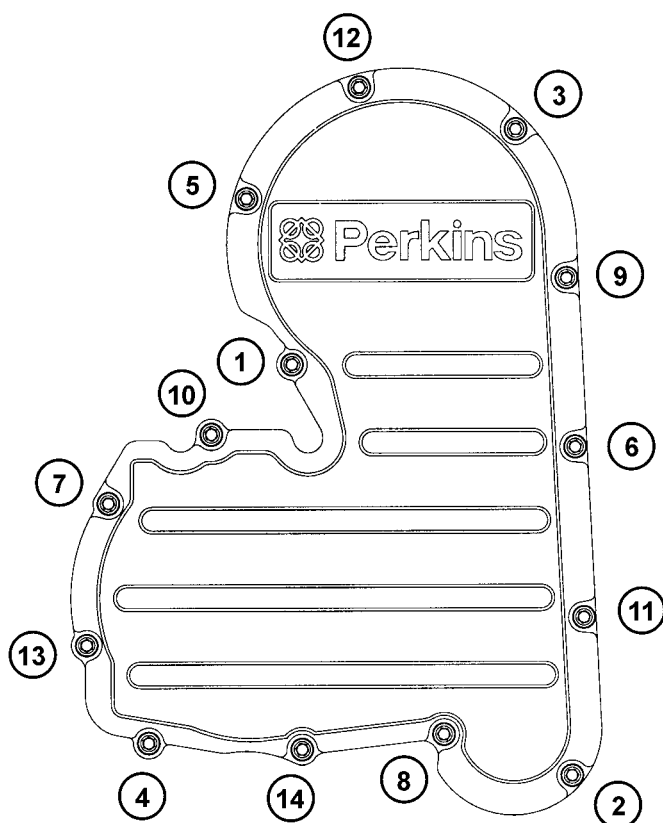
#### To remove

- 1 Remove the radiator, see Operation 12-4.
- 2 Remove the fan, see Operation 12-5.
- 3 Loosen the setscrews which retain the gear case cover. Do not remove the setscrews from the assembly, allow them to be retained by the seal.
- 4 Remove the gear case cover.

#### To fit

**Note:** Ensure that all contact surfaces of the seal and the gear case are clean and free from oil, paint, burrs or debris.

- 1 Examine the seal and renew if necessary, clean the contact surfaces of the seal and the gear case.
- 2 Fit the gear case cover and tighten the setscrews, in the sequence (A), to a torque of 20 Nm (15 lbf ft) 2 kgf m.
- 3 Fit the fan, see Operation 12-5.
- 4 Fit the radiator, see Operation 12-4.



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## Camshaft gear

To remove

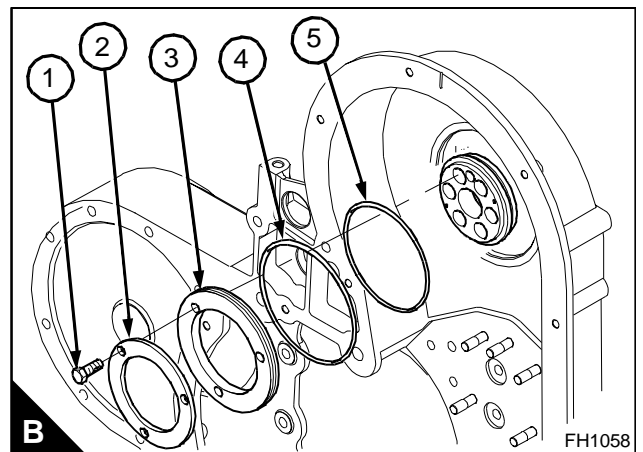
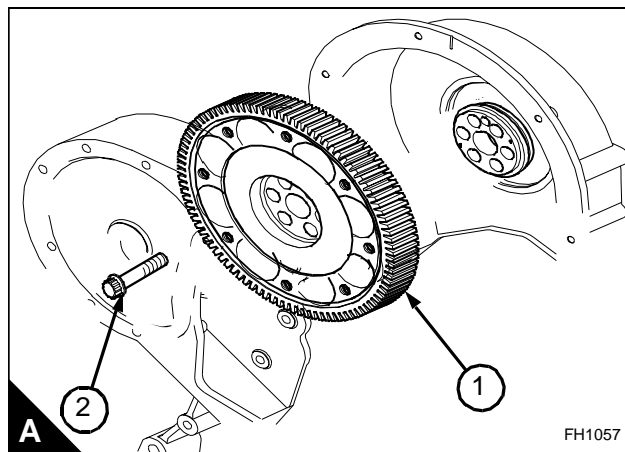
Operation 6-2

### Special requirements

Special tools		Consumable products	
Description	Part number	Description	Part number
Guide bolt, camshaft gear	GE50019	POWERPART Thread lock and nutlock	21820117
Bolt	GE50009		

- 1 Remove the rocker levers see Operation 3-3.
- 2 Remove the gear case cover, see Operation 6-1.
- 3 Loosen the torx screws (A2).
- 4 Set the engine to TDC on number one cylinder compression stroke, see Operation 8-1.

**Note:** Ensure that the timing marks on the gears are aligned.



- 5 Remove one of the torx screws (A2) and fit the guide bolt GE50019 to the camshaft.
- 6 Remove the all the other torx screws.
- 7 Remove the camshaft gear (A1).
- 8 Remove the guide bolt.

**Caution:** Do not rotate the crankshaft with the camshaft gear or any of the idler gears removed and the rocker shaft assemblies installed. Damage can be caused to the pistons and valves, or to both.

- 9 If the cylinder head or camshaft is to be removed the items shown in (B) must be removed.

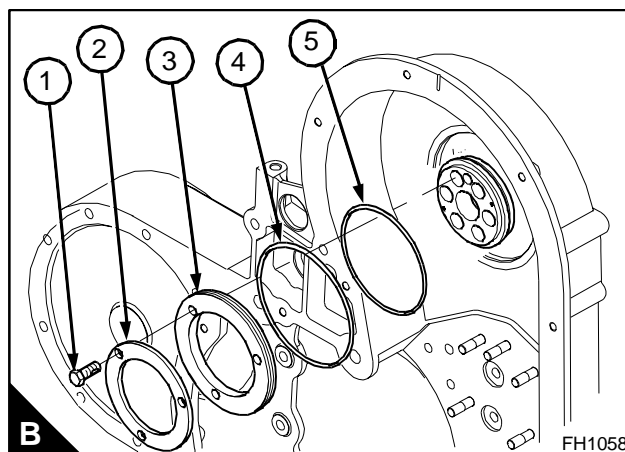
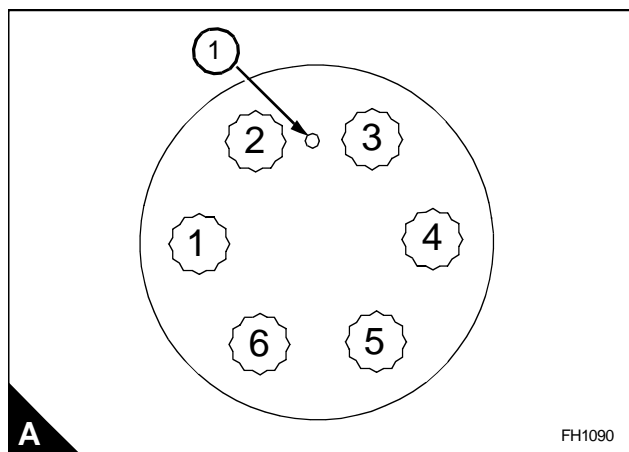
## To fit

## Operation 6-3

- 1 Ensure that the engine is on TDC number one on compression stroke, see Operation 8-1.
- 2 Ensure that all components are clean and free from damage. Renew as necessary.
- 3 If removed fit items (B). Renew the 'O' ring (B4) and (B5). Lubricate both 'O' rings with clean engine lubricating oil.

**Note:** Ensure that the 'O' rings are correctly fitted in there grooves in (B3).

- 4 Fit the plate (B3) onto the camshaft and against the cylinder head.
- 5 Fit the plate (B2) and apply POWERPART Threadlock and nutlock, 21820117, to the setscrews, fit the setscrews and tighten to a torque of 28 Nm (21 lbf ft) 2,8 kgf m.
- 6 Fit the guide bolt GE50019.
- 7 Align the hole in the camshaft gear with the dowel pin (A1) on the adapter plate. If the timing mark on the gear does not align with the pointer at the top of the gear case, remove the gear and rotate the camshaft until the gear can be installed with the marks aligned. Ensure that the timing marks on the crankshaft gear and compound idler are aligned.
- 8 Fit the torx screws. Remove the guide bolt and fit the last torx screw.



- 9 Number the torx screws in sequence (A). Ensure that the dowel (A1) is to the top. Tighten the torx screws to the numbered sequence 1, 4, 2, 5, 3, 6, 1, and 4, and to a torque of 240 Nm (177 lbf ft) 24,4 kgf m.
- 10 Check the camshaft gear back lash, see Operation 6-6.
- 11 Fit the gear case cover, see Operation 6-1.
- 12 Fit the rocker levers see, Operation 3-3.

## Adjustable idler gear and axle

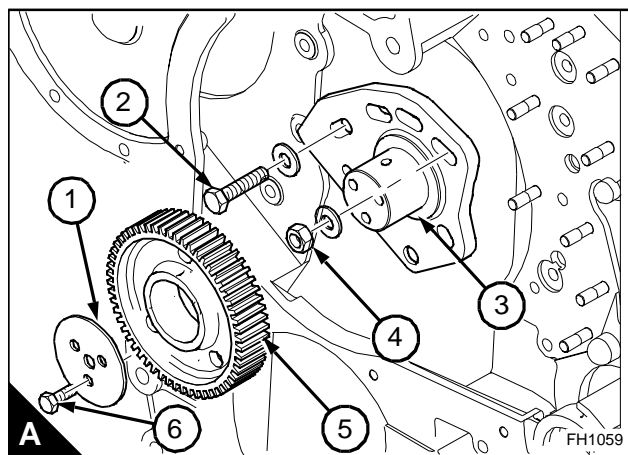
To remove

Operation 6-4

## Special requirements

Consumable products	
Description	Part number
POWERPART Threadlock and nutlock	21820117

- 1 Remove the camshaft gear, see Operation 6-2.
- 2 Remove the setscrew (A6) and the plate (A1).
- 3 Remove the gear (A5).
- 4 Remove the setscrew (A2) and the nuts (A4). Remove the axle (A3).



To fit

Operation 6-5

- 1 Ensure that all components are clean and free from damage. Renew as necessary.
  - 2 Align the axle (A3) to the gear case and fit new setscrew (A2) and nuts (A4). If necessary apply POWERPART Threadlock and nutlock, 21820117 and tighten to 50 Nm (37 lbf ft) 5 kgf m.
  - 3 Lubricate the axle with clean engine lubricating oil. Align the idler gear (A5) to the axle and fit.
  - 4 Align the plate (A1) and apply POWERPART Threadlock and nutlock, 21820117 to the setscrews (A6). Tighten the setscrews to 28 Nm (21 lbf ft) 2,8 kgf m.
- Caution:** If the axle (A3) or cylinder head or any gear has been removed the back lash must be checked, see Operation 6-6.
- 5 Fit the camshaft gear, see Operation 6-3.

## How to set the backlash for the camshaft gear

## Operation 6-6

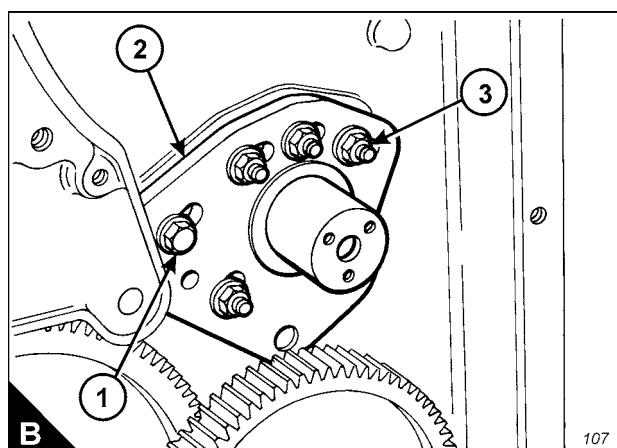
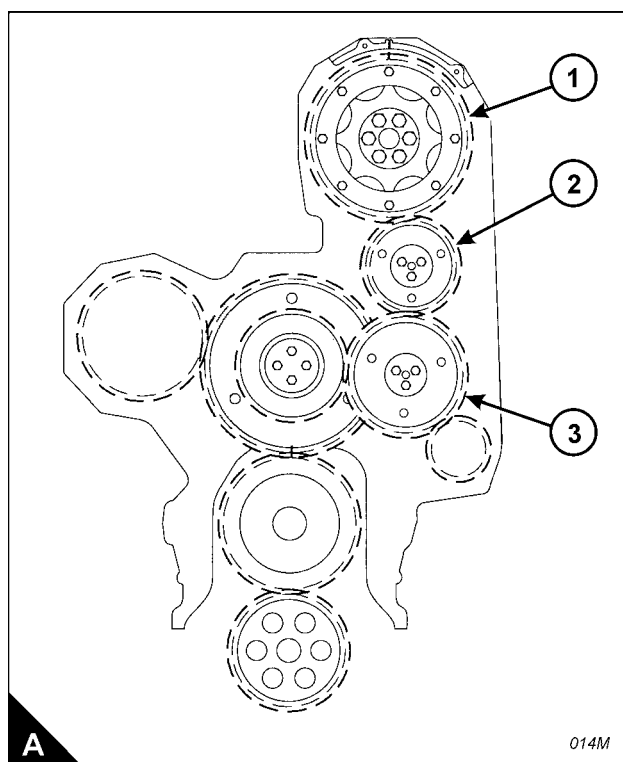
## Special requirements

Consumable products	
Description	Part number
POWERPART Threadlock and nutlock	21820117

If the cylinder head or the camshaft is removed, the backlash between the camshaft gear (A1) and the adjustable idler gear (A2) must be checked and, if necessary, adjusted. The backlash between the camshaft gear and the adjustable idler gear, and also between the adjustable idler gear (A2) and the main idler gear (A3), must be  $0,25 \pm 0,08$  mm ( $0.010 \pm 0.003$  in).

**Note:** This procedure must be performed before the rocker lever and shaft assemblies are fitted.

- 1 Remove the main idler gear (A3). Hold the camshaft gear stationary and use a dial test indicator (DTI), mounted on the gear case, to check the backlash of the adjustable idler gear.
- 2 Fit the main idler gear (A3), hold the main idler gear stationary and measure the backlash on the adjustable idler gear.
- 3 To adjust the backlash, remove the three setscrews and thrust plate which retain the adjustable idler gear (A2) and remove the gear. Loosen the five nuts (B3) and the setscrew (B1) which retain the stub axle (B2) and move the stub axle by the relevant amount. Tighten the nuts and setscrew to a torque of 50 Nm (37 lbf ft) 5 kgf m.



- 4 Fit the idler gear. Fit with the thrust plate and three setscrews. Check the backlash between the adjustable idler gear and the camshaft gear. Then check between the adjustable idler gear (A2) and the main idler gear (A3), as given in steps 1 and 2. Repeat the procedure if necessary until the correct backlash settings have been obtained.

*Continued*

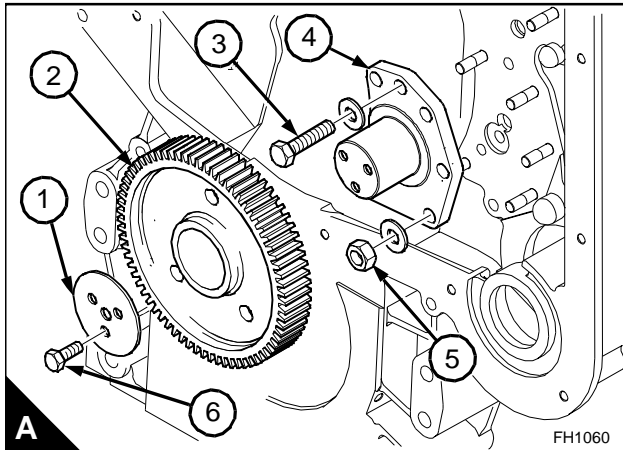
**5** When the backlash is correct, remove the adjustable idler gear. Remove one of the nuts which retains the idler axle, apply POWERPART Threadlock and nutlock 21820117 to the threads of the stud, fit the nut and tighten to a torque of 50 Nm (37 lbf ft) 5 kgf m. Repeat this procedure for the other four nuts and the setscrew; work on one nut or setscrew at a time so that the position of the stub axle is not affected.

## Main Idler gear

### To remove

### Operation 6-7

- 1 Remove the camshaft gear, see Operation 6-2.
- 2 Remove the adjustable idler gear, see Operation 6-4.
- 3 Remove the setscrews (A6) and remove the plate (A1).
- 4 Remove the gear (A2).



- 5 Remove the setscrew (A3) and the nuts (A5) and discard. Remove the axle (A4).

### To fit

### Operation 6-8

#### Special requirements

Consumable products	
Description	Part number
POWERPART Threadlock and nutlock	21820117

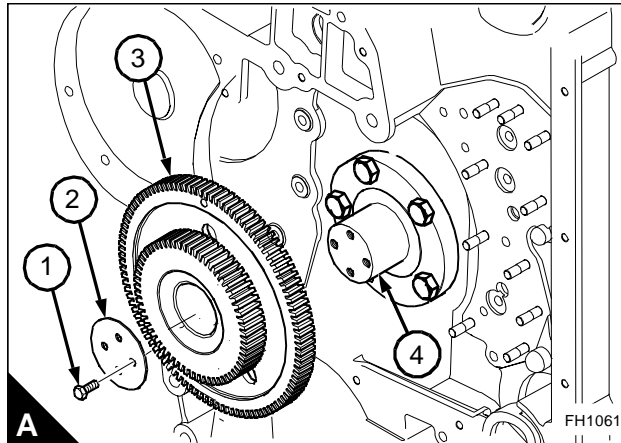
**Caution:** Some setscrews used on the axles of the gears are a special locking setscrew. These setscrews use a material similar to nylon in order to lock the setscrew. Perkins engine company limited recommend that these setscrews are discarded after use. If the setscrews are used again they must have POWERPART Threadlock and nutlock 21820117 applied to the threads.

- 1 Ensure that all components are clean and free from damage. Renew as necessary.
- 2 Align the axle (A4) to the gear case. If necessary apply POWERPART Threadlock and nutlock 21820117 to the setscrew and studs.
- 3 Fit the setscrew and nuts (A3) (A5) and tighten them to 50 Nm (37 lbf ft) 5 kgf m.
- 4 Lubricate the axle with clean engine lubricating oil.
- 5 Fit the gear (A2).
- 6 Align the plate (A1), apply POWERPART Threadlock and nutlock to the setscrews and tighten to 28 Nm (20 lbf ft) 2,8 kgf m.
- 7 Fit the adjustable idler gear, see Operation 6-5.
- 8 Fit the camshaft gear, see Operation 6-3



**Compound idler gear****To remove****Operation 6-9**

- 1 Remove the main idler gear Operation 6-7.
- 2 Remove the four setscrews (A1) and the plate (A2).
- 3 Remove the gear (A3).

**To fit****Operation 6-10****Special requirements**

Consumable products	
Description	Part number
POWERPART Threadlock and nutlock	21820117

**Caution:** Some setscrews used on the axles of the gears are a special locking setscrew. These setscrews use a material similar to nylon in order to lock the setscrew. Perkins engine company limited recommend that these setscrews are discarded after use. If the setscrews are used again they must have POWERPART Threadlock and nutlock 21820117 applied to the threads.

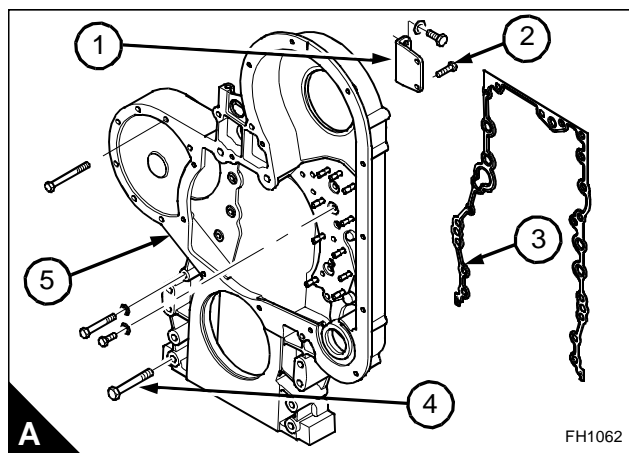
- 1 Ensure that all components are clean and free from damage. Renew as necessary.
- 2 Lubricate the axle (A4) with clean engine lubricating oil.
- 3 Fit the gear (A3) onto the axle.
- 4 Align the plate (A2), apply POWERPART Threadlock and nutlock 21820117 to the setscrews and tighten to 50 Nm (37 lbf ft) 5 kgf m.
- 5 Fit the main idler gear, see Operation 6-8.

## Gear case

### To remove

### Operation 6-11

- 1 Remove the gear case cover, see Operation 6-1.
  - 2 Disconnect the lead and remove camshaft timing sensor from behind the top of the gear case.
  - 3 Disconnect the lead and remove crankshaft timing sensor from behind the bottom of the gear case.
  - 4 Remove the coolant pump, see Operation 12-16.
  - 5 Remove the crankshaft vibration damper, see Operation 5-6.
  - 6 Remove the front engine support, see Operation 7-1.
  - 7 Remove the sump, see Operation 10-5.
  - 8 Remove the fuel transfer pump, see Operation 11-4. If necessary, remove the drive for the fuel transfer pump, see Operation 11-5.
  - 9 Remove camshaft gear, see Operation 6-2.
  - 10 Remove the adjustable idler and axle, see Operation 6-4.
  - 11 Remove main idler and axle, see Operation 6-7.
  - 12 Remove the idler compound gear, see Operation 6-9.
  - 13 Remove the setscrews (A2) and the bracket (A1).
  - 14 Remove the setscrews (A4) and remove the gear case (A5).
- Note:** The gear case is fitted onto the dowels that align the gear case to the crankcase. Use suitable lift equipment in order to remove the gear case. The weight of the gear case is approximately 62 kg (137 lb).
- 15 Remove the joint (A3) and discard.



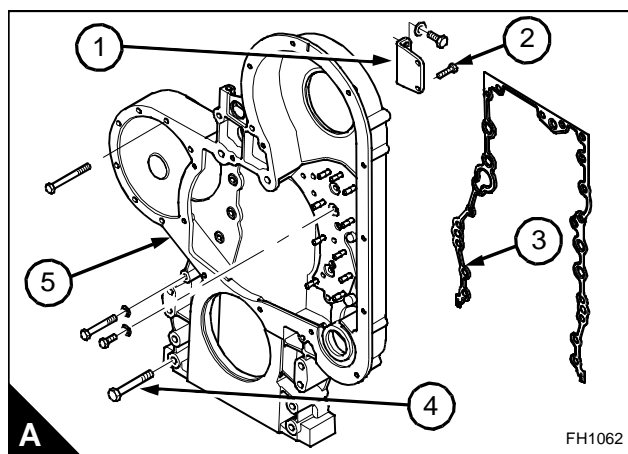
## To fit

## Operation 6-12

- 1 Ensure that all components are clean and free from damage. Renew as necessary.
- 2 Fit the joint (A3) to the crank case.

**Notes:**

- If the dowels are renewed ensure that they protrude from the crankcase by 19,1 mm (0.75 in).
  - Use suitable lift equipment to fit the gear case. The weight of the gear case is approximately 62 kg (137 lb).
- 3 Align the gear case (A5) to the dowels and fit.
  - 4 Fit the setscrews (A4) and tighten to 50 Nm (37 lbf ft) 5 kgf m.



- 5 Align the bracket (A1) and fit the setscrews (A2) and tighten securely.
- 6 Fit the idler compound gear, see Operation 6-10.
- 7 Fit the axle and the main idler, see Operation 6-8.
- 8 Fit the axle and the adjustable idler, see Operation 6-5.
- 9 Fit camshaft gear, see Operation 6-3.
- 10 Fit the fuel transfer pump, see Operation 11-4.
- 11 Fit the gear case cover see Operation 6-1.
- 12 Fit the sump, see Operation 10-5.
- 13 Fit the front engine support, see Operation 7-1.
- 14 Fit the crankshaft vibration damper, see Operation 5-6.
- 15 Fit the coolant pump, see Operation 12-16.
- 16 Fit the crankshaft timing sensor from behind the bottom of the gear case and connect the lead.
- 17 Fit the camshaft timing sensor from behind the top of the gear case and connect the lead.

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# 7

## Crankcase and cylinder liners

### General information

**Warning!** Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

The crankcase is a single unit casting made from high quality cast iron and consists of the crank chamber and the cylinder block. The crank chamber extends below the centre of the crankshaft to ensure strength. The crankshaft is supported in seven bearings secured by removable caps and fitted with thrust washers at the centre bearing. The cylinder block contains a row of six cylinders arranged vertically. Wet-type cylinder liners are used, these are manufactured from cast iron and are induction hardened. A steel spacer plate is fitted to the top face of the crankcase. This improves the strength and durability when compared with conventional designs.

## Front engine support

To remove and to fit

Operation 7-1

### To remove

1 Remove the radiator, see Operation 12-4.

**Note:** Use suitable lift equipment in order to lift bracket.

2 Lift the front of the engine. Support the engine and remove the setscrews (A2) which retain the front mounting support (A3) to the base frame.

3 Remove the eight setscrews and washers (A1) and remove the engine support.

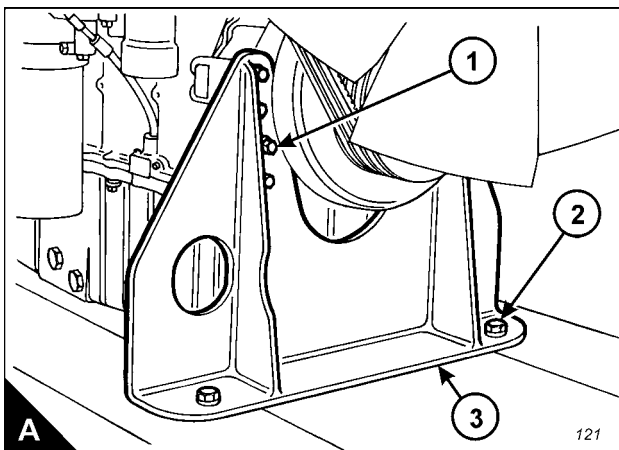
The weight of the front engine support is approximately 34 kg (74 lb).

### To fit

1 Fit the front engine support to the engine and retain with eight setscrews and washers (A1). Tighten the setscrew to 100 Nm (73 lbf ft) 10,1 kgf m.

2 Attach the engine support to the base frame with the relevant setscrews (A2), remove the lift equipment from the bracket and tighten the setscrews.

3 Fit the radiator, see Operation 12-4.



## Cylinder liners

To remove and to fit

Operation 7-2

## Special requirements

Special tools		Consumable products	
Description	Part number	Description	Part number
Cylinder liner remover	GE50001	Anti-seize compound	CV60890
Cylinder liner installer	GE50000		

## To remove

- 1 Remove the pistons and connecting rod assemblies, Operation 4-1.
- 2 Fit covers over the journals of the crankshaft for protection from dirt or water.
- 3 Use the special tool (A1) GE50001 to remove the cylinder liners (A2). Make a note of the bore position to which each liner is fitted.

## To fit

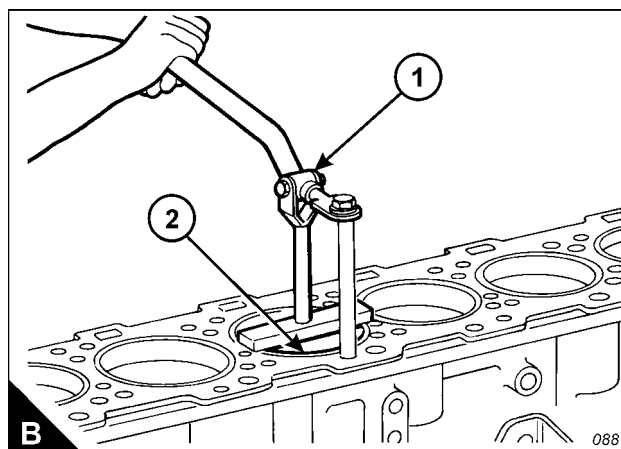
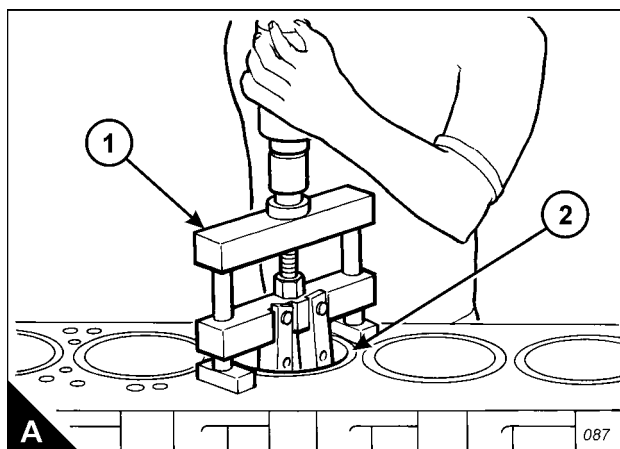
- 1 Clean the cylinder liners and the liner bores in the cylinder block.
- 2 Install the cylinder liners in the cylinder block without the 'O' ring seals or the filler band. Ensure that the cylinder liners are fitted to their original positions.
- 3 Check the protrusion of the cylinder liners, see Operation 7-3.
- 4 Remove the liners and fit new 'O' ring seals.

**Note:** Apply liquid soap and/or clean engine lubricating oil immediately before assembly. Do not apply the liquid soap and/or clean engine lubricating oil to the seals too early as the seals may swell and become pinched by the liners during installation.

- 5 When the engine is ready for final assembly, lubricate the 'O' ring seals, the cylinder block and the upper filler band before installation. If the lower 'O' ring seals are black in colour, apply liquid soap to them and to the cylinder block, and immerse the upper filler band in clean engine lubricating oil. If the lower 'O' rings are brown in colour, apply engine lubricating oil to them, to the cylinder block and immerse the upper filler band in clean engine lubricating oil.

- 6 After the engine lubricating oil or liquid soap has been applied, immerse the filler band in clean engine lubricating oil, then immediately fit the filler band to the groove in the cylinder liner below the liner flange. Immediately install the cylinder liner in the crankcase before expansion of the band occurs. Use the special tool (B1) GE50000, to install the liners (B2). Ensure that the liners are fitted to the correct positions.

- 7 Fit the pistons and connecting rod assemblies, see Operation 4-1.



## To check and to adjust the protrusion of the cylinder liners

## Operation 7-3

## Special requirements

Special tools			
Description	Part number	Description	Part number
Clamp bolt	GE50005	Fibre washer	GE50007
Clamp washer	GE50006	Cylinder liner projection tool	GE50002

**Note:** Cylinder liner protrusion is measured from the top of the cylinder liner to the top of the spacer plate.

- 1 Ensure that the top face of the crank case (A4) is clean. Fit a new spacer plate gasket and fit a clean spacer plate (A3).
- 2 Fit the cylinder liners to the cylinder block without seals or bands. Ensure that the cylinder liners are fitted to their original positions.
- 3 Install all of the setscrews (A6) GE50005 or the six setscrews around the liner (A5) to be checked. A plain washer (A1) GE50006 and a fabric washer (A2) GE50007 must be fitted to each setscrew. Tighten the setscrews to a torque of 95 Nm (70 lbf ft) 9,6 kgf m.
- 4 Use the special tool GE50002 to measure the liner protrusion at the four positions shown (B1, B2, B3 and B4) and record the measurements for each cylinder.
- 5 Add the four readings for each cylinder and divide the sum of the readings by four to obtain the average reading for each cylinder.

The correct specifications for cylinder liner protrusion are:

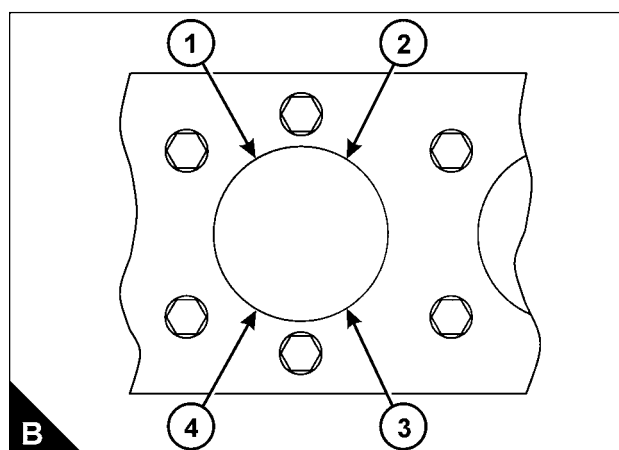
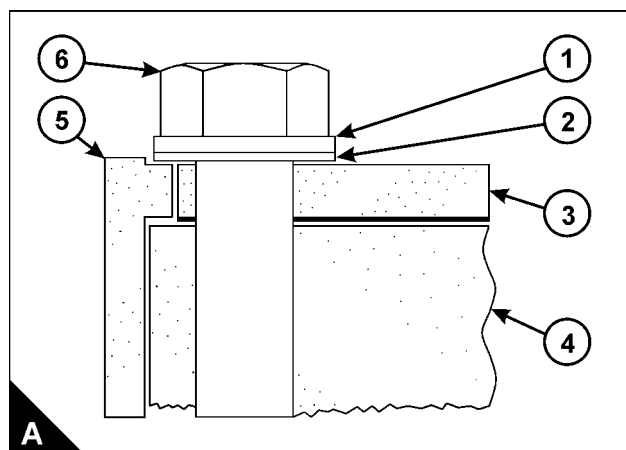
Liner protrusion: 0,025 to 0,152 mm (0.001 to 0.006 in)

Maximum variation in each liner: 0,051 mm (0.0020 in)

Maximum average variation between adjacent liners: 0,051 mm (0.0020 in)

Maximum variation between all liners: 0,102 mm (0.0040 in).

**Note:** If the liner protrusion changes around the liner, turn the liner to a new position within the bore. If the liner protrusion is not within the specifications, move the liner to a different bore. Inspect the top face of the cylinder block.



*Continued*



**6** If the liner protrusions are all below the specifications or low in the range, 0,025 mm (0.001 in) or 0,051 mm (0.002 in), try a thinner spacer plate, available from your Perkins dealer or distributor. These plates are 0,076 mm (0.003 in) thinner than the original plate and will increase the liner protrusion. Use these spacer plates to compensate for low liner protrusions which are less than the 0,076 mm (0.003 in). Use these spacer plates if inspection of the top face of the cylinder block reveals no measurable damage directly under the liner flanges but the average liner protrusion is less than 0,076 mm (0.003 in).

**Caution:** Do not exceed the maximum liner protrusion of 0,152 mm (0.006 in). Excessive liner protrusion will cause the liner flange to crack.

**7** When the liner protrusion is correct, add a temporary mark to the liner and to the spacer plate to assist with the assembly procedure. Remove the setscrews and washers, and withdraw the cylinder liners.

**8** When the engine is ready for final assembly, the 'O' ring seals, the cylinder block and the upper filler band must be lubricated before installation. If the lower 'O' ring seals are black in colour, apply liquid soap to them and to the cylinder block. Immerse the upper filler band in clean engine lubricating oil. If the lower 'O' rings are brown in colour, apply engine lubricating oil to them and to the cylinder block. Immerse the upper filler band in clean engine lubricating oil.

**Note:** Apply liquid soap and/or clean engine lubricating oil immediately before assembly. Do not apply the liquid soap and/or clean engine lubricating oil to the seals too early as the seals may swell and become pinched by the liners during installation.

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# 8

## Engine timing

### General information

The electronic control system used on the 2806-18 litre engine, consists of the Electronic Control Module (ECM) and engine sensors. The ECM is mounted on the left side of the engine, and controls the engine operating parameters. The software stores the operating maps which define power, engine speed, etc. electronic fuel unit injectors are fitted to each cylinder. A solenoid on each injector controls the amount of fuel delivered by the injector. The ECM sends a signal to each injector solenoid to provide complete control of the engine. The ECM compares the 'desired speed' with the actual engine speed, obtained from sensors on the crankshaft and camshaft drives, and calculates how much fuel to inject to achieve the desired speed.

The timing of the fuel injection is determined by the ECM after it has received information from the coolant temperature sensor, the air temperature sensor of the inlet manifold and the turbocharger boost pressure sensor. From a signal provided by the engine speed/timing sensor, the ECM determines where top dead centre on cylinder number one is located. The ECM decides when injection should occur relative to top dead centre and provides a signal to the fuel injector at the desired time. The ECM adjusts timing for the best engine performance, fuel economy and white smoke control. Actual or desired timing can be viewed with the service tool.

The ECM controls the amount of fuel injected by varying signals to the fuel injector. The ECM sends a high voltage signal to energise the solenoids of the fuel injectors. The fuel injectors will pump fuel only if the fuel injector solenoid is energised.

**Warning!** *The electrical circuit for the fuel injector units operates on 110 volts. Do not work on the fuel injector units unless the power supply to the ECM has been disconnected.*

The software inside the ECM sets limits on the amount of fuel that can be injected dependent on the selected rating and the engine operating parameters. The parameters which follow are monitored by the ECM: High coolant temperature, low lubricating oil pressure, overspeed condition, inlet manifold air temperature, fuel temperature and boost pressure.

The electronic system has some ability to diagnose itself. When a diagnostic code is generated, the 'Diagnostics' lamp is illuminated and the exact fault should be determined by use of the service tool. Full information on fault finding the system is given in the Diagnostic Manual TSD 3453.

The ECM communicates with the service tool through the Perkins Data Link (PDL); a connector is normally fitted to the wiring harness to enable the service tool to be connected. A J1939 data link is also available in addition to the Perkins Data Link.

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**Engine timing**

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To set number 1 piston to TDC on the compression stroke

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**Operation 8-1**

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**Special requirements**

Special tools	
Description	Part number
Engine turning tool	CH11148

**Caution:** *If a customer-fitted speed sensor is fitted to the flywheel housing, it must be removed before the engine turning tool can be installed.*

**Note:** This operation can be carried out from either side of the flywheel housing.

- 1 Remove the rocker cover, see Operation 3-1.
- 2 Remove the setscrew (A1). Remove the two setscrews (A3) and (A4).
- 3 Remove the blanking plate (A2) and fit the engine turning tool CH11148.

*Continued*

**4** To set the No 1 piston to TDC on the correct stroke. Use a  $\frac{1}{2}$  inch drive ratchet in the turning tool, carefully rotate the crankshaft in the normal direction of rotation until the intake valve of number 6 cylinder has just opened and the exhaust valve of the same cylinder has not closed completely.

**5** Rotate the crankshaft in the opposite direction for approximately 45 degrees. Slowly rotate the crankshaft in the normal direction of rotation until the threaded hole in the flywheel is aligned with the setscrew hole (A1).

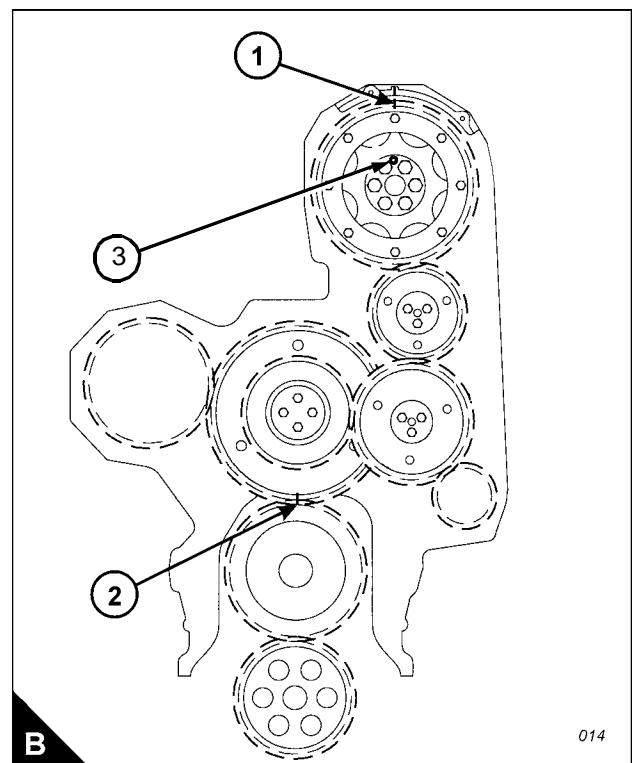
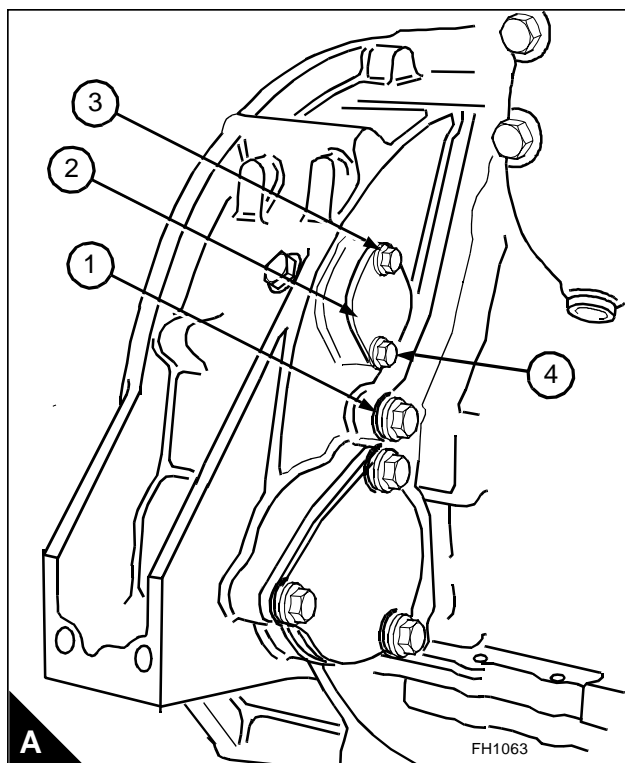
**6** Use the setscrew (A3), fit the setscrew through the setscrew hole (A1) and into the threaded hole in the flywheel.

**Caution:** If the threaded hole in the flywheel is rotated past the threaded hole (A3), the flywheel must be rotated in the opposite direction for approximately 45 degrees and then back in the normal direction of rotation until the setscrew (A3) engages with the threaded hole in the flywheel. This is to eliminate backlash.

With the valves on number 6 cylinder set and the setscrew fitted into the flywheel in (A1) the engine is timed on number 1 cylinder on compression stroke.

#### Notes:

- (B1) and (B2) show the alignment of the timing gears mark with the engine timed to TDC number one on compression stroke. Timing mark (B2) is only viewed with the sump removed.
- The gear timing may be check with the sump fitted.
- Set the No 1 piston to TDC, see Operation 8-1. Check the alignment of the dowel (B3) to the timing marks (B1) on the gear case and gear. When the dowel is aligned to the timing mark (B1) and the setscrew (A3) is fitted into the flywheel in position (A1) the No 1 piston is at TDC on the compression stroke and the gear timing is correct.



**7** Remove the setscrew (A3) from the threaded hole in (A1).

**8** Fit the blanking plate (A2) and the setscrews (A3) and (A4) and tighten securely.

**9** Fit the setscrew (A1) and tighten securely.

**10** Fit the rocker cover, see Operation 3-2.

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# 9

## Aspiration system

### General information

**Warning!** Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

The induction system of the engine is supplied with air under pressure by twin turbochargers. The turbochargers are driven by the energy of the exhaust gas.

Special thermal sleeves manufactured from stainless steel are fitted to the exhaust ports. These reduce the amount of heat transferred to the cooling system and direct the thermal energy to the turbocharger.

The exhaust gas passes through the exhaust manifold and enters the turbine housing of the turbocharger. The pressure of the exhaust gas causes the turbine rotor to rotate, the gas then leaves the engine through the exhaust pipes. Exhaust pipes and exhaust silencers are fitted in accordance with the requirements of the installation. An impeller at the other end of the turbine shaft supplies clean air to the engine at more than atmospheric pressure. The air is drawn through the air cleaner and into the compressor housing which contains the impeller. From the compressor housing the air is forced through the air-to-air charge cooler which is integral with the radiator. The air is cooled as it flows through the charge cooler, this improves the combustion efficiency. From the charge cooler the air is directed through air ducts to the cylinder head and enters the cylinders of the engine.

A restriction indicator is fitted next to the casing of the air filter to give a visual indication when the filter element is dirty. The air filter needs no special maintenance, except for the procedures given in the User's Handbook TPD 1516.

The engine breather is an integral part of the rocker cover. If the breather becomes blocked or damaged, the assembly of the rocker cover should be renewed, see Operation 3-1.

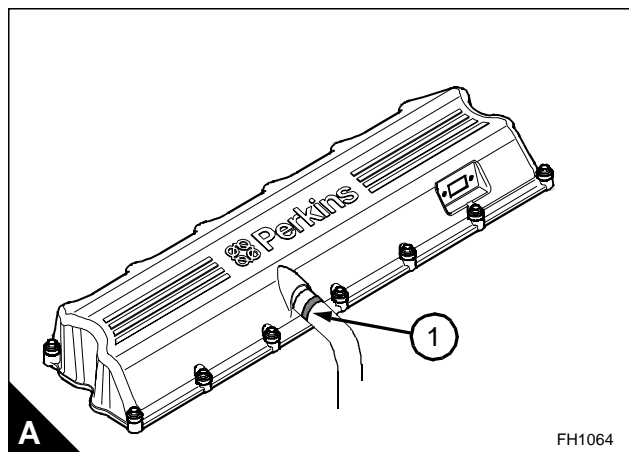
## Breather pipe

To remove and fit

**Operation 9-1**

### To remove

- 1 Loosen the clip (A1) and remove the breather pipe.
- 2 Ensure that dirt can not enter the engine.



### To fit

- 1 Fit the breather pipe to the rocker cover and tighten the clip securely.



## Air filter assembly

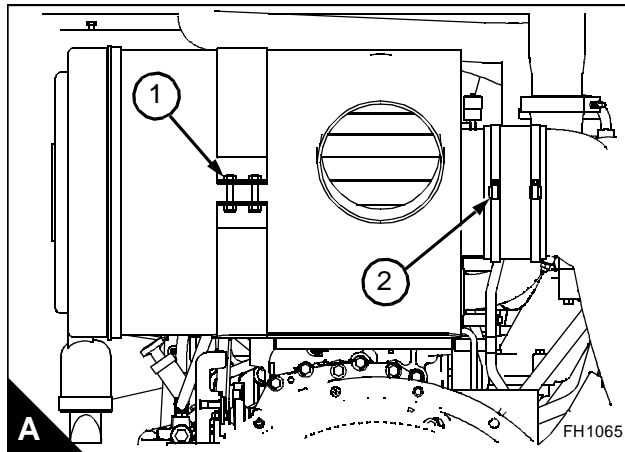
To remove and fit

Operation 9-2

**Note:** Use suitable lift equipment in order to lift the air filter assembly.

### To remove

- 1 Remove the nuts and bolts (A1) and loosen the clip (A2).
- 2 Remove the air filter assembly. Ensure that debris can not enter the induction system.



### To fit

- 1 Align the air filter assembly to the induction system and fit into the hose.
- 2 Check the alignment and the angle of the air filter assembly is correct.
- 3 Fit the nuts and bolts (A1) and tighten both (A1) and (A2) securely.

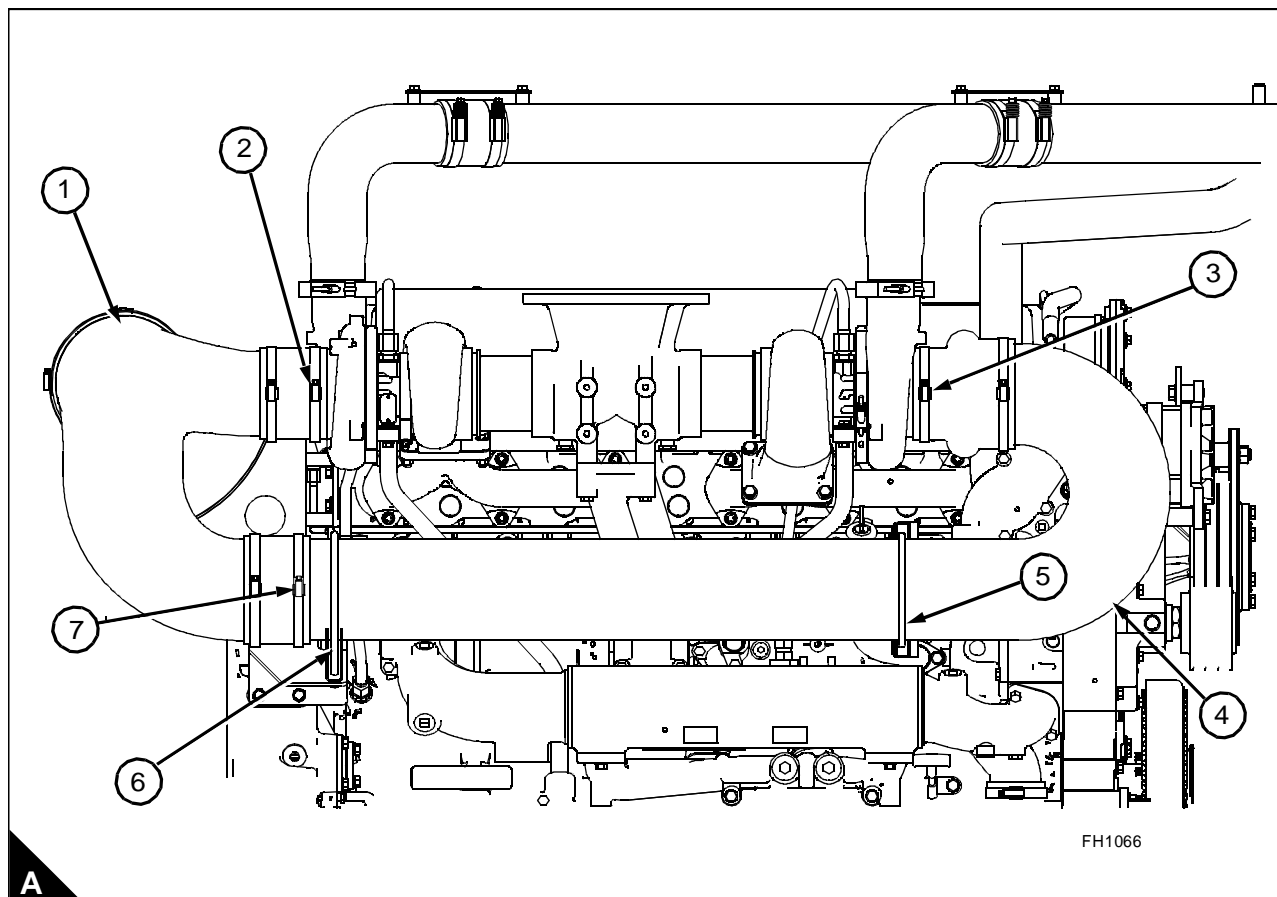
## Air intake system

To remove

### Operation 9-3

**Note:** Use suitable lift equipment in this procedure.

- 1 Remove the air filter assembly, see Operation 9-2.
- 2 Loosen the clips (A2) and (A7). Remove the first part of the induction system (A1).



- 3 Loosen the clips (A3).
- 4 Remove the clamps (A5) and (A6).
- 5 Remove the second part of the induction system (A4).

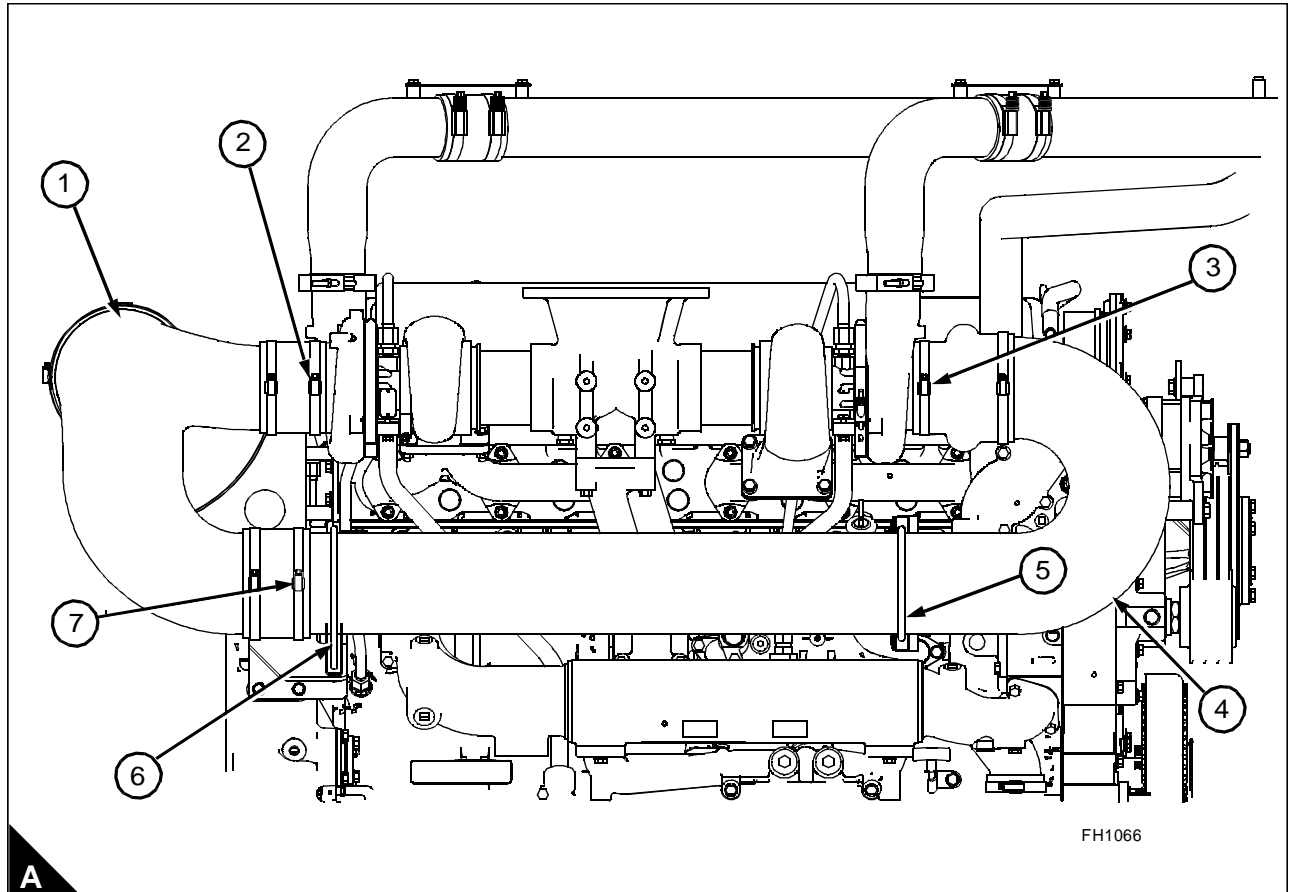
**Note:** Ensure that debris can not enter the induction system.

## To fit

## Operation 9-4

**Note:** Use suitable lift equipment in this procedure.

- 1 Align the induction assembly (A4) and fit on to turbocharger, loosely fit the clamps (A5) and (A6).
- 2 Align the induction assembly (A1) to the turbocharger and to the assembly (A4). Fit them together.
- 3 Check the alignment of the induction system. Tighten the clamps (A5) and (A6) securely. Tighten the clips (A2), (A3) and (A7) securely.



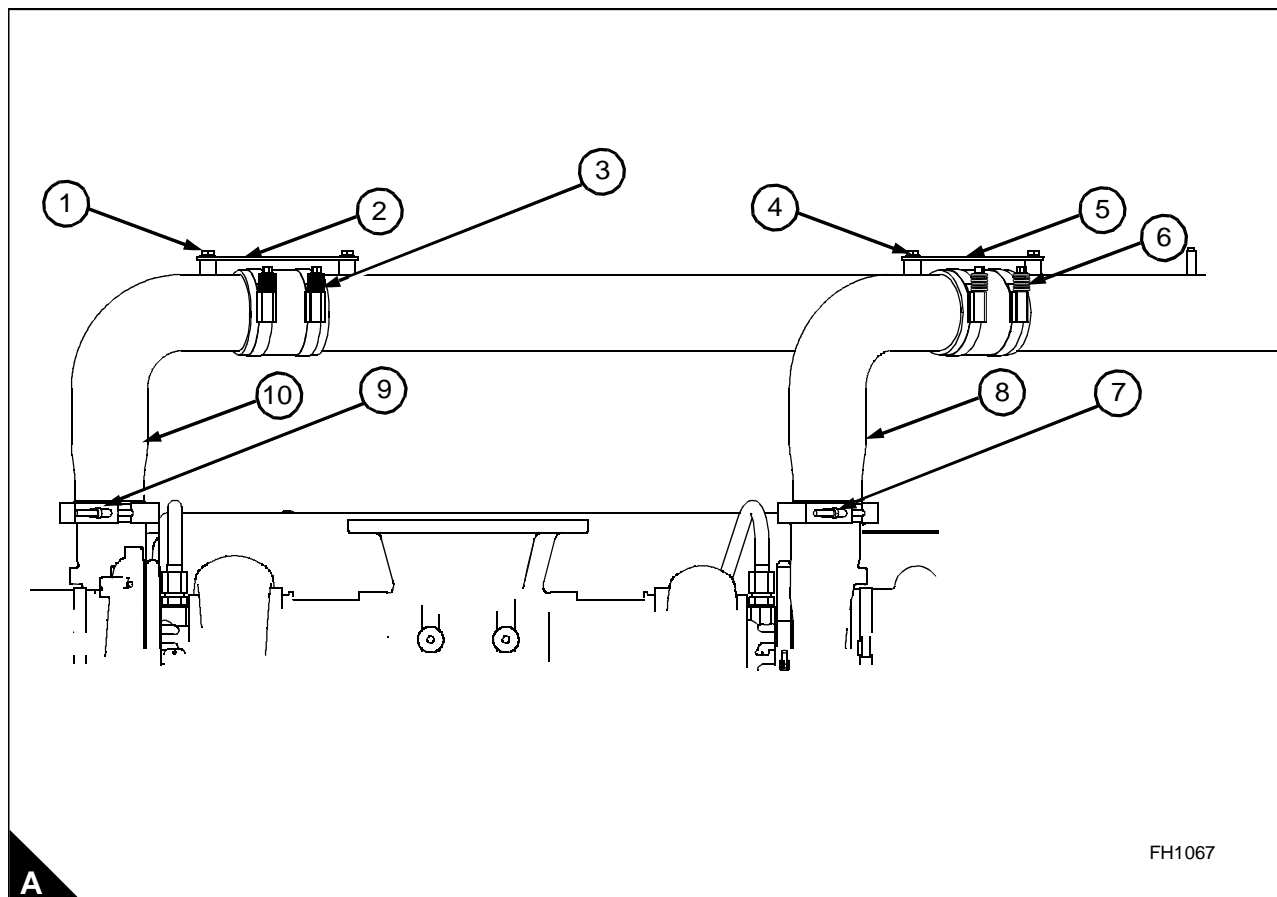
- 4 Fit the air filter assembly, see Operation 9-2.

**Charger cooler pipes**

To remove and fit

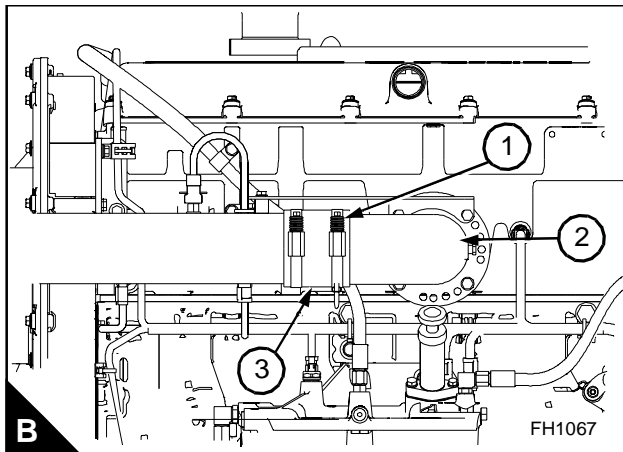
**Operation 9-5****To remove**

- 1 Remove the intake system, see Operation 9-3.
- 2 Loosen the clips (A3) and (A6). Remove the setscrews (A1) and (A4). Remove link plates (A2) and (A5).



- 3 Loosen the clamps (A7) and (A9) and remove both elbows (A8) and (A10).

*Continued*



4 Loosen the two clips (B1) and remove the hose (B3) from the intake elbow (B2).

**Notes:**

- Remove or support the remainder of the pipes.
- Ensure that debris can not enter the system.

**To fit**

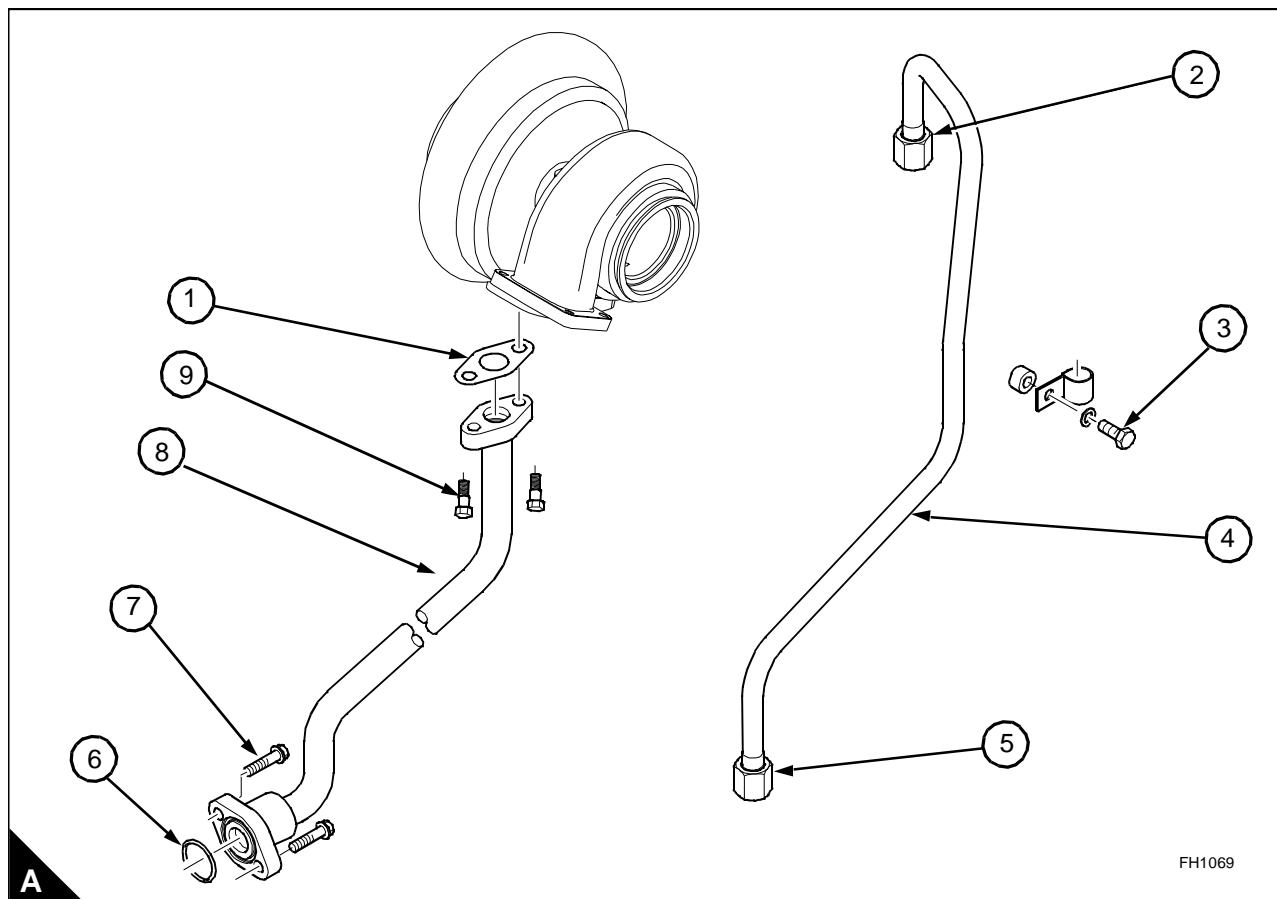
- 1 Align the elbows (A8) and (A10). Fit to turbochargers and to the pipes.
- 2 Align link plates (A2) and (A5). Fit the setscrews (A1) and (A4), tighten securely.
- 3 Tighten clamps (A7) and (A9) securely. Tighten clips (A3) and (A6) securely.
- 4 Fit the hose (B3) on to the elbow (B2) and tighten the clip (A1) securely
- 5 Fit the intake system, see Operation 9-4.

## Turbocharger

### To remove

### Operation 9-6

- 1 Disconnect the exhaust pipe from the turbocharger.
- 2 Remove the induction system from the turbocharger and the air cleaner, see Operation 9-3.
- 3 Disconnect the pipes from the turbochargers and the charge air cooler, see Operation 9-5.
- 4 Remove the setscrews (A9) and (A7). Remove both the oil drain pipes (A8).
- 5 Remove both top joint (A1) and both bottom seal (A6).
- 6 Remove the setscrew (A3) and the clip complete with the washer and spacer.



- 7 Disconnect the unions (A2) and (A5). Remove both the oil supply pipes (A4).

*Continued*

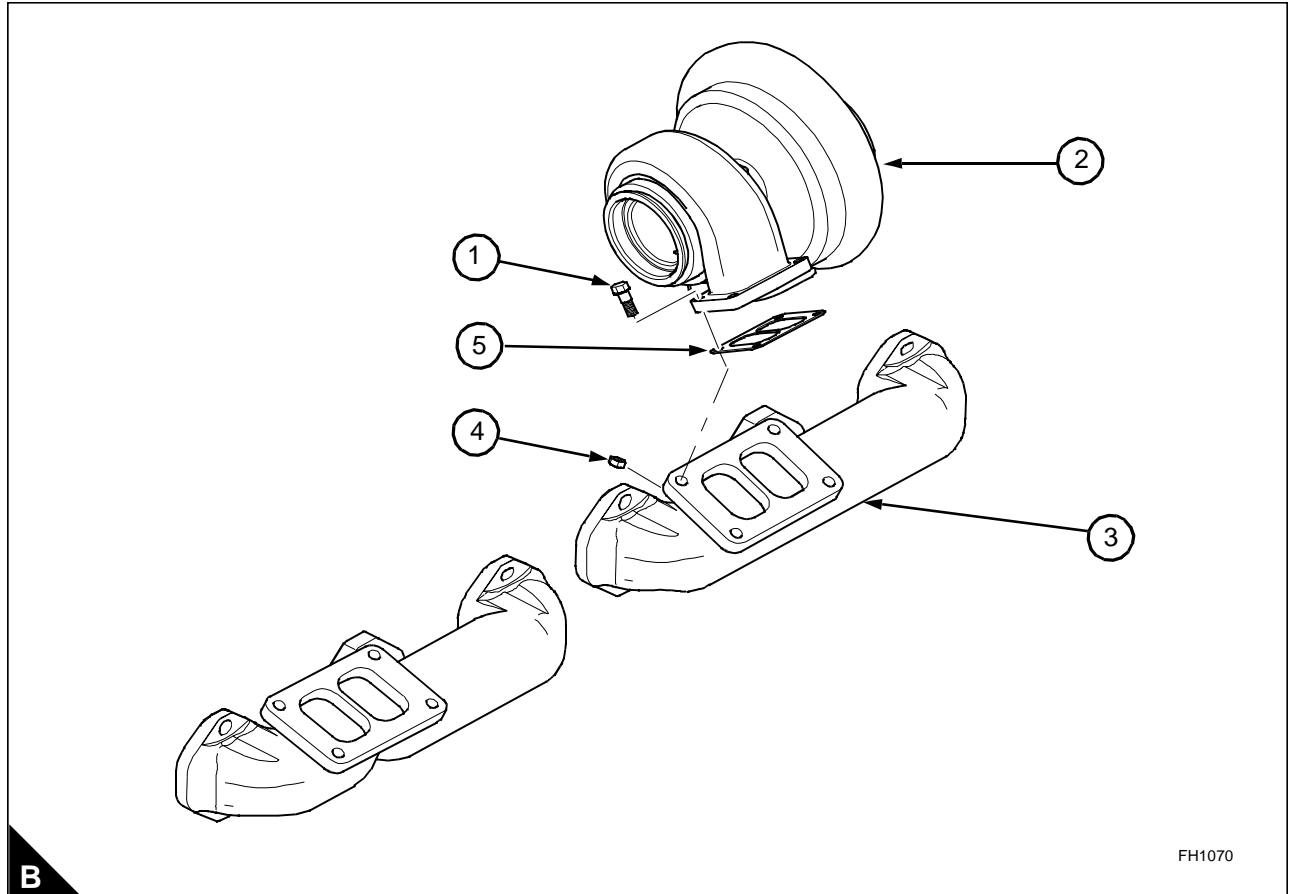
**8** Remove the four nuts and bolts (B4) and (B1) from each of the turbochargers.

**Note:** Use suitable lift equipment in order to lift the turbochargers. Each turbocharger weighs approximately 26.5 kg (58 lb).

**9** Remove the turbochargers (B2).

**10** Remove the gasket (B5) from both exhaust manifolds (B3).

**11** Discard all used joints and seals.



To fit

Operation 9-7

**Special requirements**

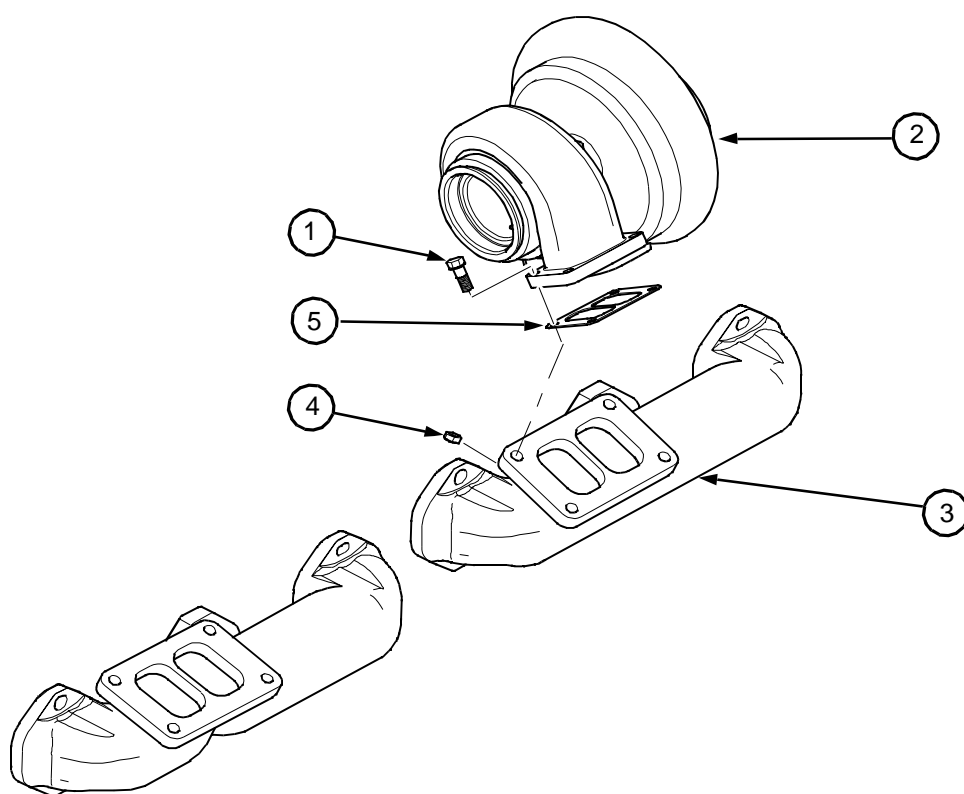
Consumable products	
Description	Part number
Anti-seize compound	CV60889

1 Ensure that all components are clean and free from damage. Renew as necessary.

**Note:** Use suitable lift equipment in order to lift the turbochargers.

2 Align the new gasket (A5) and align the turbocharger (A2) to the manifold (A3).

3 Apply CV60889 anti-seize compound to the bolts. Fit the nuts and bolts (A4) and (A1). Tighten to 55 Nm (40 lbf ft) 5,6 kgf m.



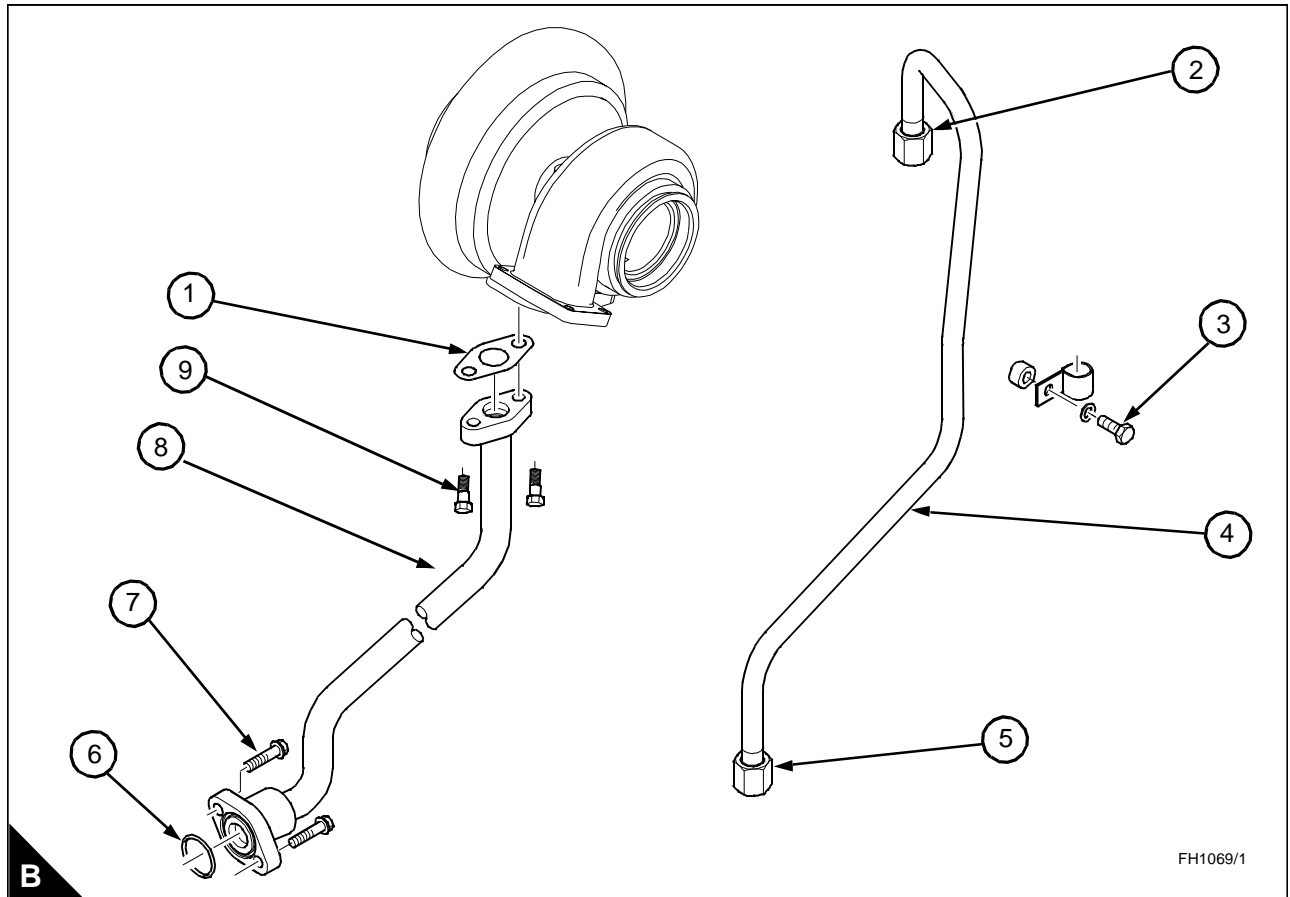
B

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*Continued*



- 4 Align the new top joint (B1) to the drain pipe (B8) and loosely fit the setscrews (B9).
- 5 Align the new bottom seal (B6) to the drain pipe and fit the setscrews (B7). Tighten both top and bottom setscrews securely. Repeat this procedure on the other turbocharger.
- 6 Connect the top and bottom unions (B2) and (B5). Fit the clip and setscrew (B3) and tighten all connection on the oil supply pipe securely. Repeat this procedure on the other turbocharger.
- 7 Fit the induction system between the turbochargers and the air cleaner, see Operation 9-4.
- 8 Connect the pipes between the turbochargers and the charge air cooler, see Operation 9-5.



- 9 Connect the exhaust pipe.

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To dismantle and to assemble

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Operation 9-8

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**To dismantle**

- 1 Remove the turbochargers, see Operation 9-6.
- 2 Add temporary alignment marks between the bearing housing and both the compressor housing and the turbine housing to ensure that the parts can be correctly aligned during the assembly operation.
- 3 Loosen the nuts on the clamps and separate the compressor housing and the turbine housing from the bearing housing.

**Caution:** Do not attempt to dismantle the turbocharger bearing housing. Do not remove the compressor wheel. The bearing housing is not serviceable and must be renewed only as a unit.

- 4 Check the condition of all components. Renew any worn or damaged components.

**To assemble**

- 1 Fit the compressor housing and the turbine housing to the bearing housing and retain with the relevant clamps.
- 2 Adjust the position of both the compressor and turbine housings until the temporary marks are aligned with those on the bearing housing. Tighten the clamp nuts to 14 Nm (10,3 lbf ft) 1.4 kgf m.
- 3 Fit the turbochargers, see Operation 9-6.

**Exhaust manifold**

To remove and to fit

**Operation 9-9****Special requirements**

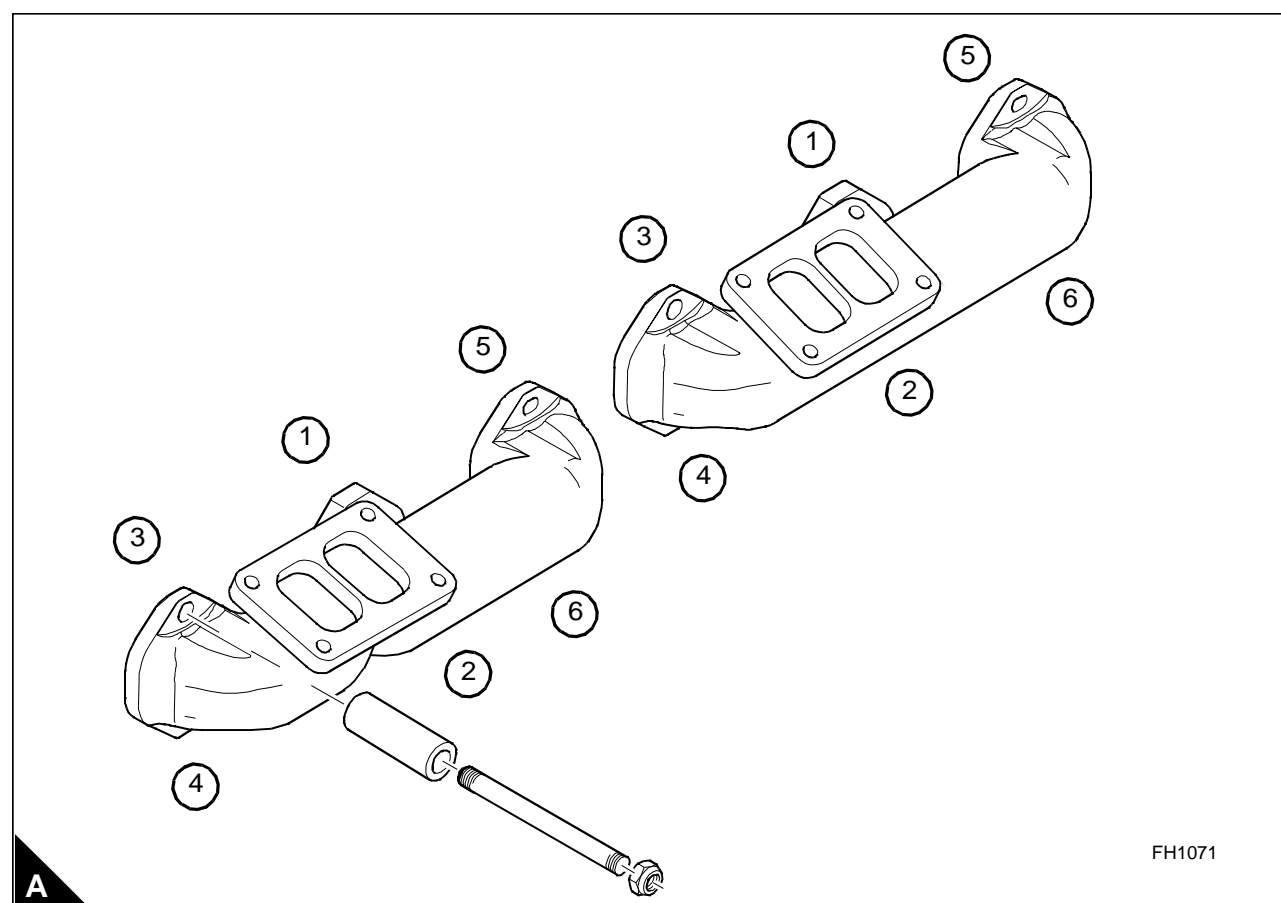
Consumable products	
Description	Part number
Anti-seize compound	CV60889

**To remove**

- 1 Remove the turbochargers, see Operation 9-6.
- 2 Remove the thermostat housing, see Operation 12-12.
- 3 Remove the exhaust shield.
- 4 Remove the nuts and spacers which retain the exhaust manifold and remove the exhaust manifold.
- 5 Remove the sleeves from the cylinder head.
- 6 Remove the gaskets from the cylinder head.

**To fit**

- 1 Check the condition of all sleeves, studs and nuts. Renew the components if worn or damaged. Apply anti-seize compound CV60889 to the studs.
- 2 Fit new gaskets over the studs and install the sleeves. Fit the exhaust manifolds, fit the spacers and the nuts. Tighten the nuts in the sequence (A) to a torque of 52 Nm (38 lbf ft) 5,3 kgf m.



- 3 Fit the thermostat housing, see Operation 12-12.
- 4 Fit the turbocharger, see Operation 9-6.

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# 10

## Lubrication system

### General information

**Warning!** Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

A wet sump type of lubrication system is used on the engine.

The engine is fitted with a lubricating oil pump, of the spur gear type. The drive gear of the lubricating oil pump is driven by a gear on the front of the crankshaft. The oil pump draws oil from the sump through a suction strainer. A pressure relief valve, integral with the oil pump, ensures that a constant pressure is maintained.

Oil leaves the oil pump and is delivered to the main oil gallery in the crankcase. When the engine is warm, the oil passes through the oil cooler and oil filter before it enters the main oil gallery. When the engine is cool, the high viscosity of the oil causes the by-pass valves to open and provide oil directly to the oil filter. To protect the engine, the by-pass valves will also open if there is a restriction in the oil cooler or the oil filter.

A supply of oil is directed to the turbochargers from the oil filter. After lubricating the turbocharger bearings, the oil drains into the crankcase and returns to the sump.

The main oil gallery is parallel to the crankshaft and supplies oil to each of the main bearings and through the main bearings to the crankshaft. The oil in the crankshaft then lubricates the connecting rod bearings. A supply of oil from the main oil gallery is directed to the piston cooling jets which cool the pistons.

An oil passage at the front end of the main oil gallery delivers oil to the cylinder head gallery and has passages which supply the bearings of the drive gears. The teeth of the drive gears are lubricated by spill oil as it returns to the sump.

Small holes in the cylinder head gallery direct oil to the camshaft bearing journals and also to the pedestals for the rocker shafts. From the pedestals the oil passes through the rocker shafts to lubricate the bearings of the valve and unit injector rocker levers. Oil flows through drilled passages in the rocker levers to lubricate the rollers, the valve bridges and the contact surfaces of the actuators for the unit injectors. Other components of the valve assembly are lubricated by splash oil. An aperture at the front of the cylinder head allows oil to drain to the sump.

The full length sump is manufactured from a composite material.

Some engines are fitted with an oil sample valve which enables a small quantity of oil to be drained for in order to be tested. Information about the oil sample valve is given in Chapter 15, Auxiliary equipment.

## Oil filter element

### To remove and fit

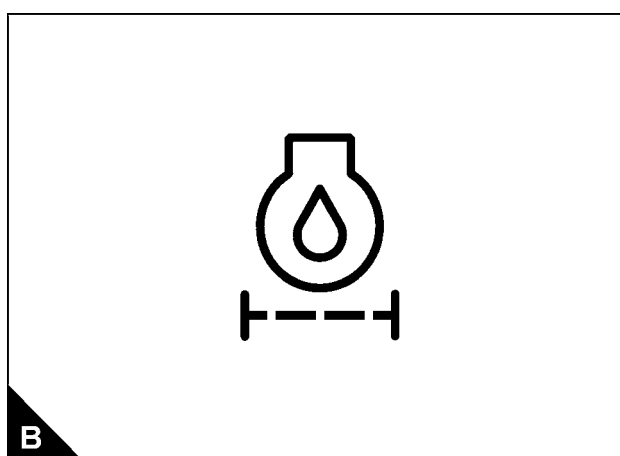
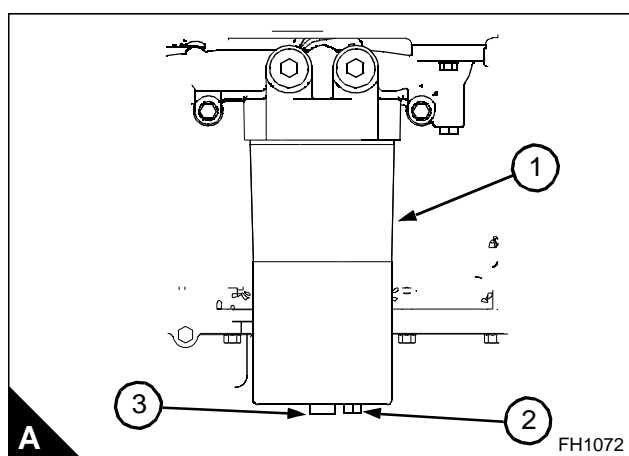
### Operation 10-1

**Warning!** Discard the used filter element, 'O' ring seal and used engine oil in a safe place and in accordance with local regulations.

**Caution:** It is important that only genuine Perkins parts are used. The use of non Perkins parts could damage the engine. The correct filter element will be marked with the symbol (B).

#### To remove

- 1 Stop the engine.
- 2 Turn the start switch to the "OFF" position. Disconnect the battery.
- 3 Position a suitable container below the lubricating oil filter.
- 4 Remove the drain plug (A2) from the base of the oil filter housing (A1) and drain the oil into the container.



- 5 Remove the filter housing (A1), remove the 'O' ring seal from the housing and remove the filter element.
- 6 Clean the housing and the filter head. Clean the drain plug (A2) and fit it to the housing.

#### To fit

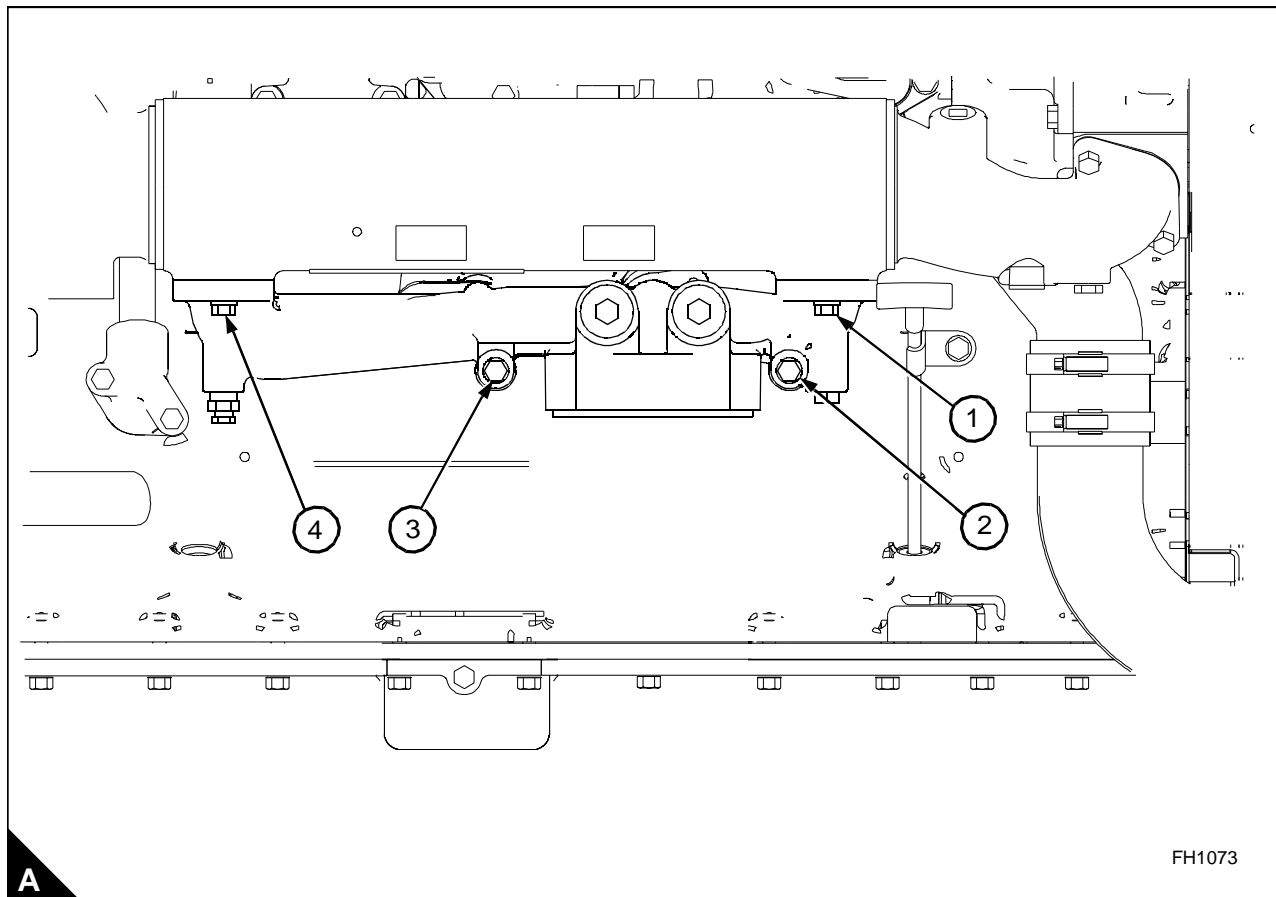
- 1 Fit a new element into the housing, ensure that it engages fully with the guide in the base of the housing. Fit a new 'O' ring seal around the top of the housing.
- 2 Fit the housing onto the filter head and tighten by use of a socket and torque wrench on the hexagon (A1). Tighten the housing to a torque of 80 Nm (59 lbf ft) 8,15 kgf m. Do not overtighten. Ensure that the drain plug is tightened securely.
- 3 Check the amount of engine oil in the sump. If necessary, add oil of the correct grade and specification. Refer to Users Handbook TPD1516.
- 4 Run the engine and check for leaks.

**Oil filter head**

To remove

**Operation 10-2**

- 1 Remove the oil filter housing, see Operation 10-1.
- 2 Disconnect the turbocharger oil supply pipe from the union behind the oil cooler.
- 3 Remove the setscrews (A1) and (A4) which connect the oil filter header to the oil cooler.
- 4 Remove the two setscrews (A2) and (A3) which retain the oil filter header on the crankcase.



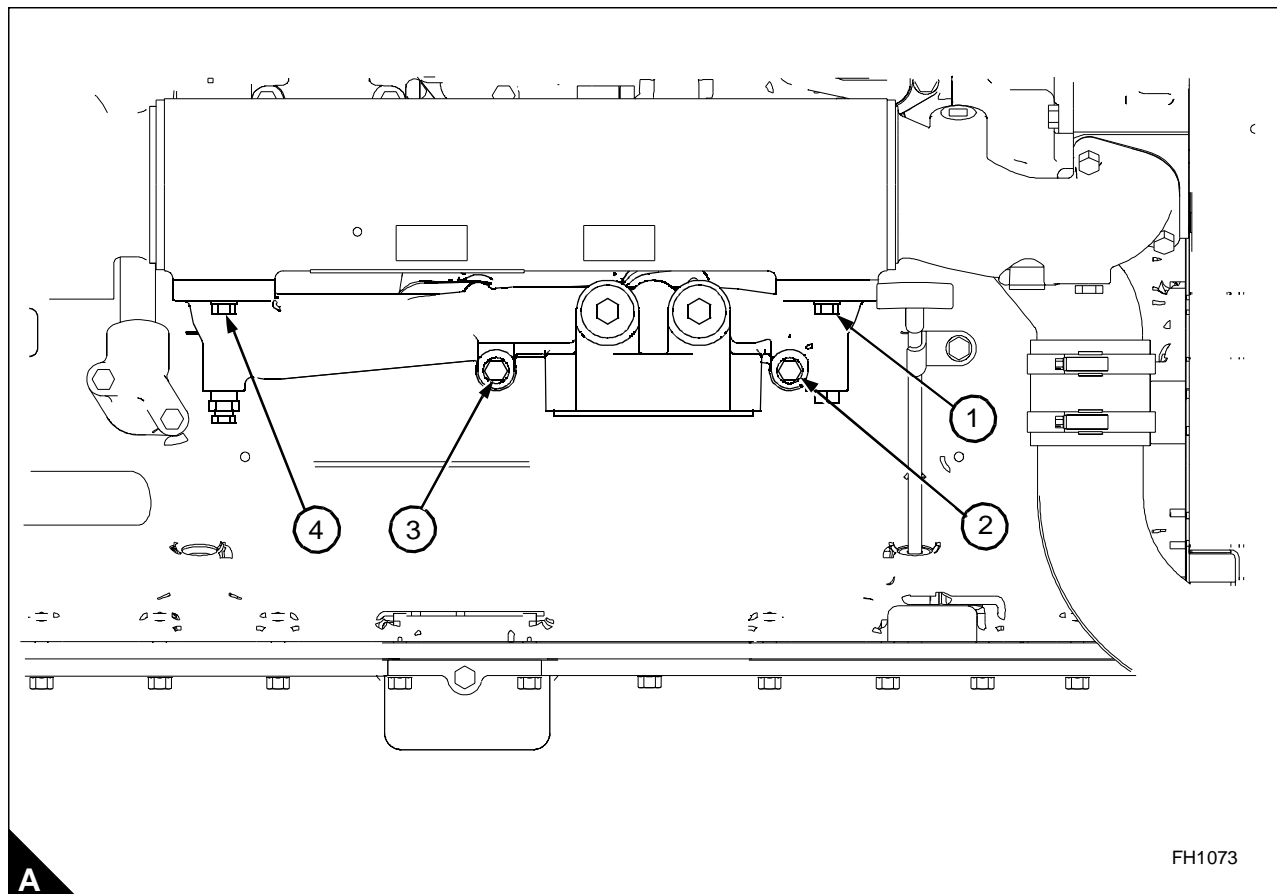
- 5 Discard the 'O' ring seals and joints.

## Oil filter head

To fit

## Operation 10-3

- 1 Ensure that all component are clean and dry.
- 2 Fit new 'O' ring seals and joints to the filter head.
- 3 Align the filter head to the oil cooler and loosely fit the setscrews (A1), (A4), (A2) and (A3).



- 4 Fit the oil supply pipe to the turbocharger and tighten the setscrews (A1), (A4), (A2), (A3) and oil supply pipe securely.
- 5 Fit the oil filter housing, see Operation 10-1.



**Oil filter header**

To dismantle and to assemble

**Operation 10-4****To dismantle**

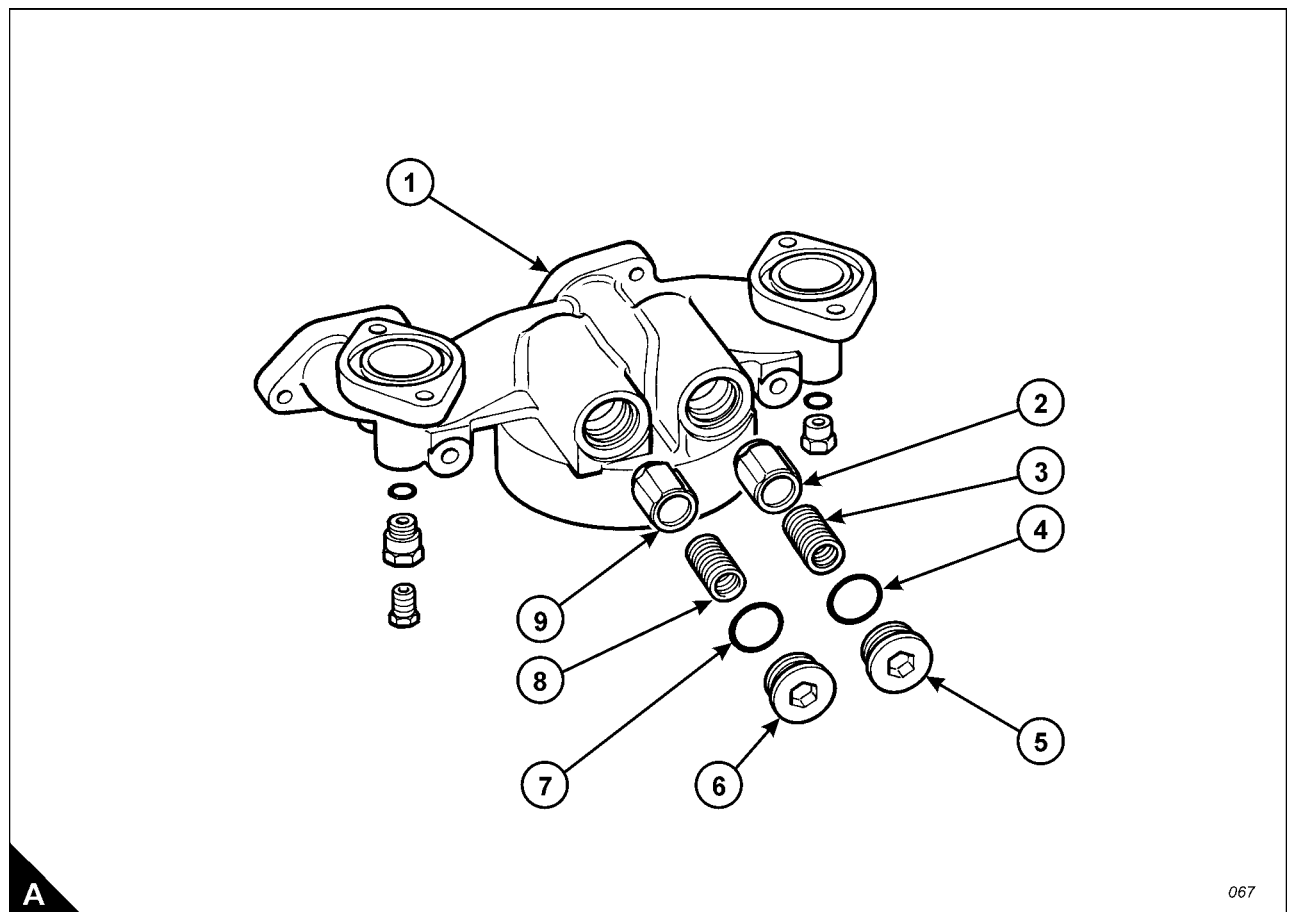
- 1 Remove the two plugs (A5 and A6) which retain the by-pass valves in the oil filter header (A1).
- 2 Remove the spring (A3) and the plunger (A2) for the oil cooler by-pass valve. Remove the spring (A8) and plunger (A9) for the oil filter by-pass valve. Add temporary marks to the two springs and plungers to assist during assembly.
- 3 Remove the two small plugs and the adaptor.

**To assemble**

Inspect the 'O' ring seals fitted to all plugs and renew them if necessary.

**Note:** Ensure that the plungers and springs are fitted to their original locations.

- 1 Fit the plunger (A9) and spring (A8) to the oil filter header.
- 2 Fit the plunger (A2) and spring (A3) to the oil filter header.
- 3 Fit the plugs (A5 and A6). Tighten each plug to 100 Nm (74 lbf ft) 10,1 kgf m.
- 4 Fit the adaptor and the two small plugs. Tighten both to a torque of 25 Nm (18 lbf ft) 2,5 kgf m.

**A**

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## Sump

To remove and to fit

## Operation 10-5

## Special requirements

Consumable products	
Description	Part number
RTV silicone sealant	CV60888

## To remove

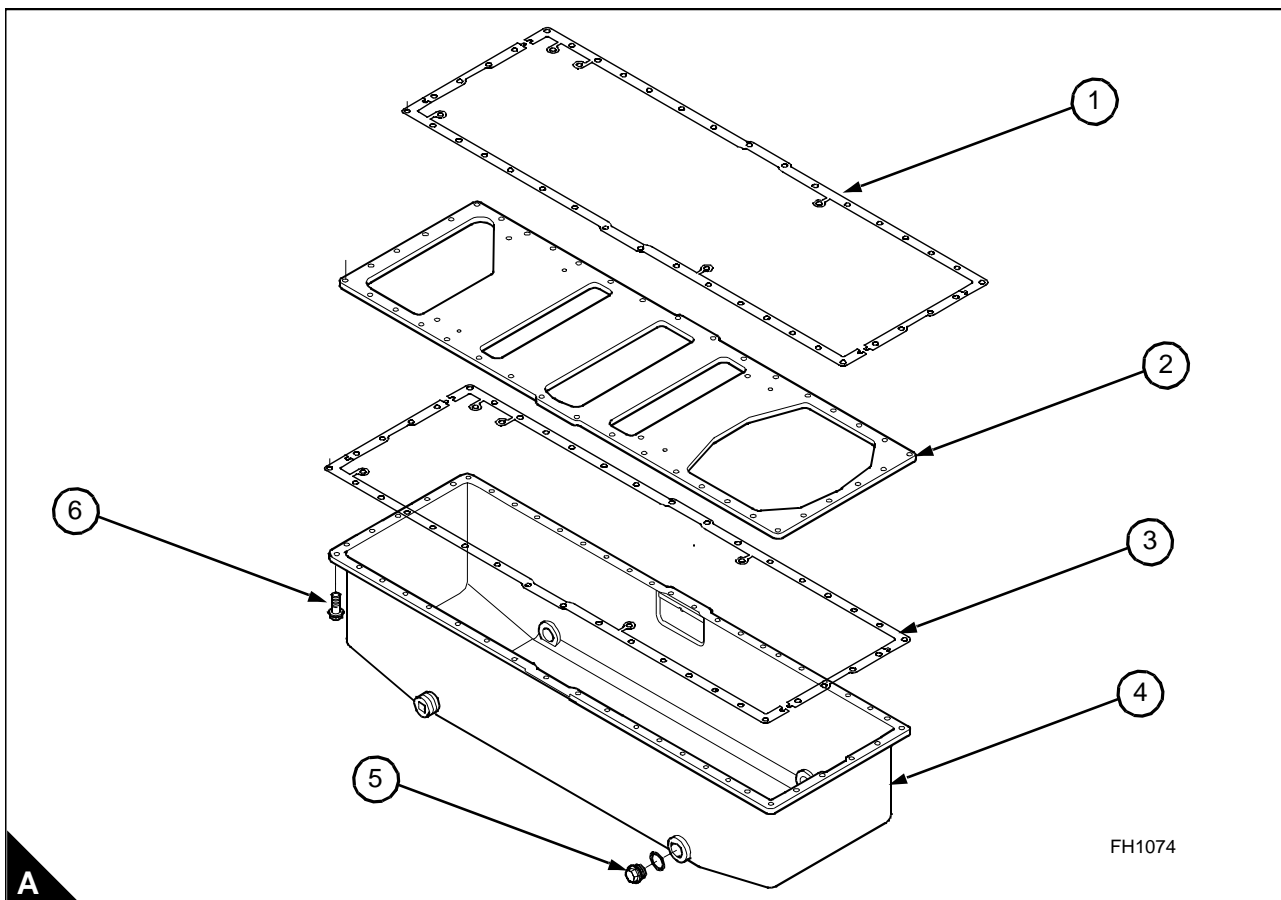
**Warnings!**

- Hot oil and components can cause personal injury. Do not allow hot oil or components to contact the skin.
- Discard the used lubricating oil in a safe place and in accordance with local regulations.

- 1 Disconnect the power supply to the starter motor.
- 2 Position a suitable container below the sump and remove the drain plug (A5).
- 3 Drain the oil from the sump.

**Note:** Use suitable lift equipment in order to remove the components.

- 4 Remove the setscrews (A6).
- 5 Remove the sump (A4) and the joint (A3).
- 6 Remove the plate (A2) and the joint (A1).

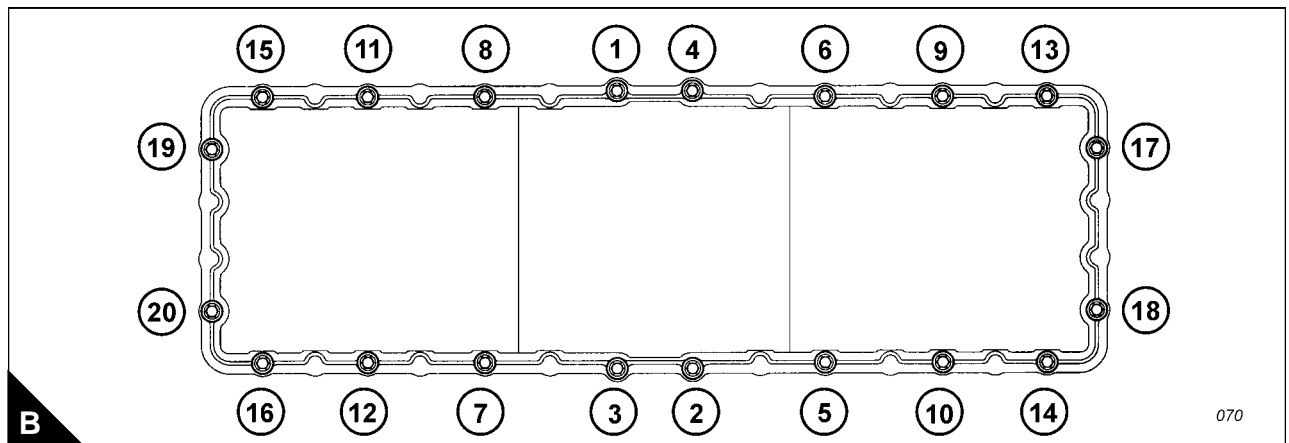


- 7 Discard the used joints.

**To fit**

**Note:** Use suitable lift equipment in order to fit the components.

- 1 Ensure that all component are clean and dry.
- 2 Apply a bead of RTV silicone sealant CV60888 at the four positions where the edge of the flywheel housing and gear case joints will be in contact with the sump joint. The bead must cover completely the exposed edge of the joints.
- 3 Fit two suitable studs at both ends of the crank case in order to guide the sump joints, plate and sump on to the gear case.
- 4 Fit the new joint (A1) and the plate (A2).
- 5 Fit the new joint (A3) and align the sump (A4). Fit the sump.
- 6 Remove the guide studs and fit the two setscrews (A6).
- 7 Tighten all the setscrews in the sequence (B). Torque the setscrews to 55 Nm (40 lbf ft) 5,6 kgf m
- 8 Fill the engine to the correct level with oil of the correct grade and specification. Refer to the User's Handbook TPD 1516.
- 9 Connect the power supply.



## Lubricating oil pump

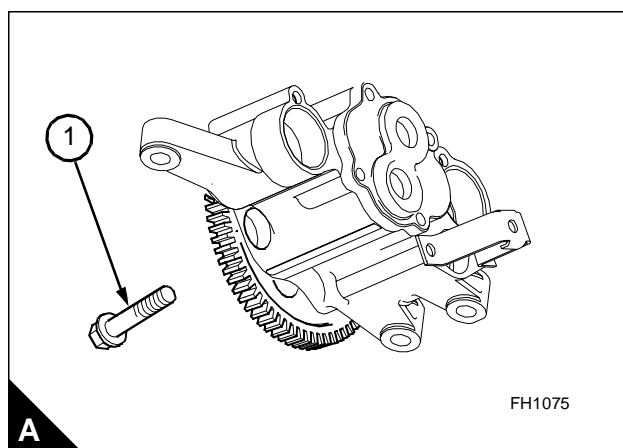
To remove and to fit

## Operation 10-6

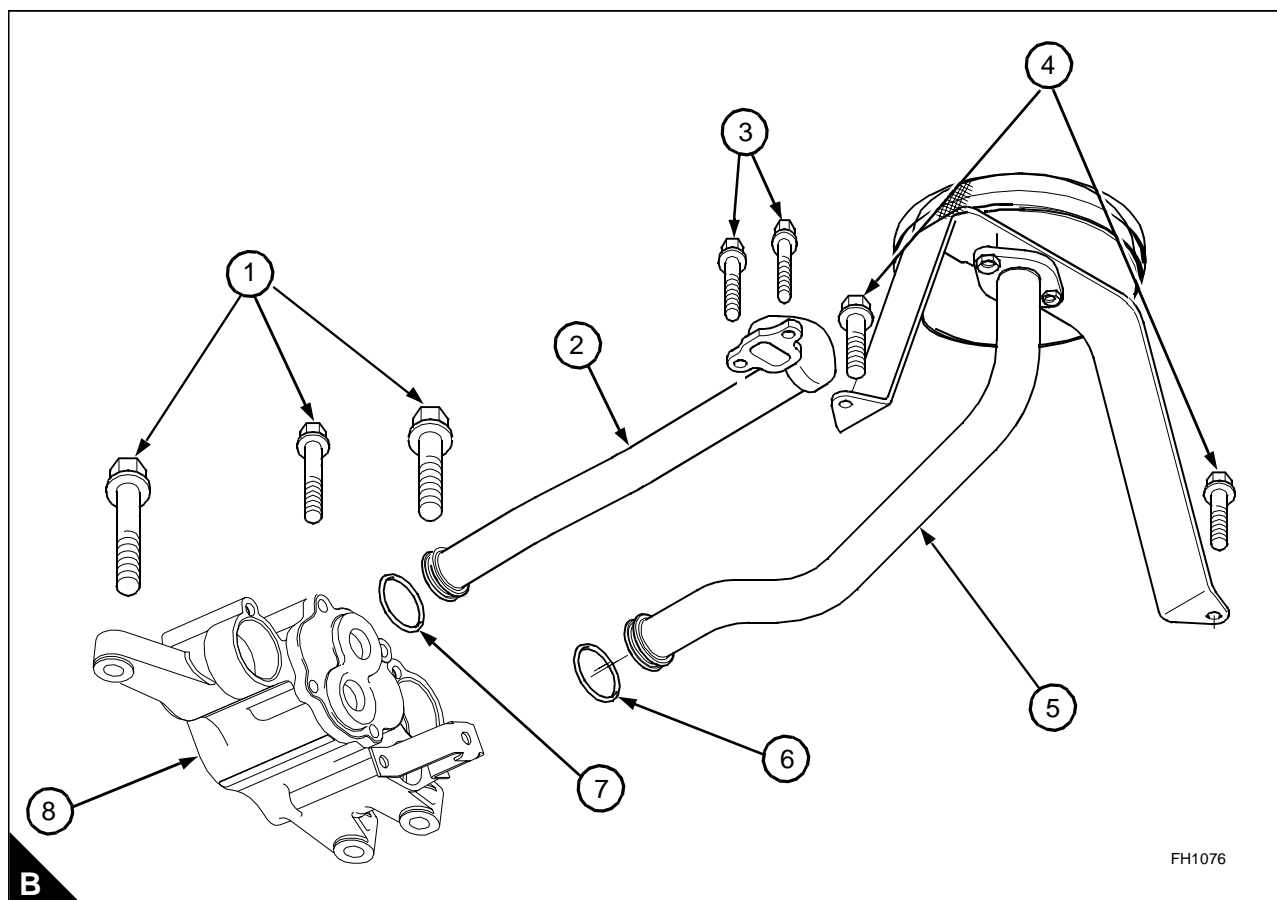
## To remove

1 Remove the sump, see Operation 10-5.

**Note:** If the oil pump is to be dismantled, loosen the setscrew (A1) which retains the drive gear before the oil pump is removed from the engine.



2 Remove the two setscrews (B4) and remove strainer assembly (B5) from the oil pump. Remove and discard the O ring (B6).



3 Remove the two setscrews (B3) and remove the oil supply tube (B2). Remove and discard the 'O' ring (B7).

4 Remove the setscrews (B1) and remove the oil pump (B8).

**To fit**

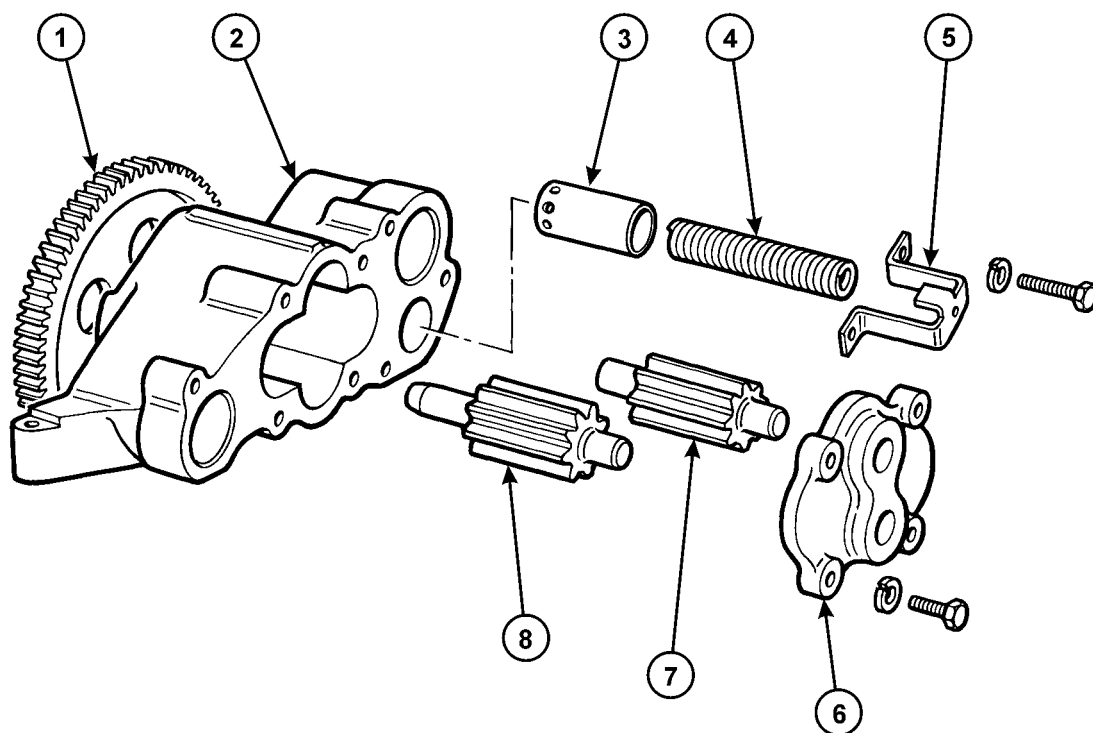
- 1** Ensure that all components are clean and dry.
- 2** Align the oil pump to the crankcase. Fit the setscrews (B1) and tighten to 47 Nm (34 lbf ft) 4,7 kgf m.
- 3** Fit new 'O' ring (B6) and (B7).
- 4** Fit the oil supply tube (B2) into the oil pump. Fit the two setscrews (B3) and tighten to 47 Nm (34 lbf ft) 4,7 kgf m.
- 5** Fit the oil strainer assembly (B5) into the oil pump. Fit the two setscrews (B4) and tighten to 47 Nm (34 lbf ft) 4,7 kgf m.
- 6** Fit the sump, see Operation 10-5.

**To dismantle**

- 1 Remove the setscrew and washer which retain the gear on the shaft.
- 2 Use a suitable gear puller to remove drive gear (A1) from the shaft. Remove the key from the shaft.
- 3 Remove retainer (A5) for the by-pass valve.
- 4 Remove the spring (A4) and the by-pass valve (A3).
- 5 Remove the cover (A6) from the pump body (A2).
- 6 Remove the idler gear and drive gear from pump body.

**To assemble**

- 1 Apply clean engine lubricating oil to the idler gear and drive gear and install the gears in the oil pump body (A2).
- 2 Fit the by-pass valve (A3) the spring (A4) and the retainer (A5) to the pump body (A2).
- 3 Fit the key to the shaft.
- 4 Fit the drive gear (A1) to the shaft. Install the washer and setscrew which retain the gear. Tighten the setscrew to a torque of 55 Nm (41 lbf ft) 5,6 kgf m. Ensure that the oil pump turns freely after assembly.



# 11

## Fuel system

### General information

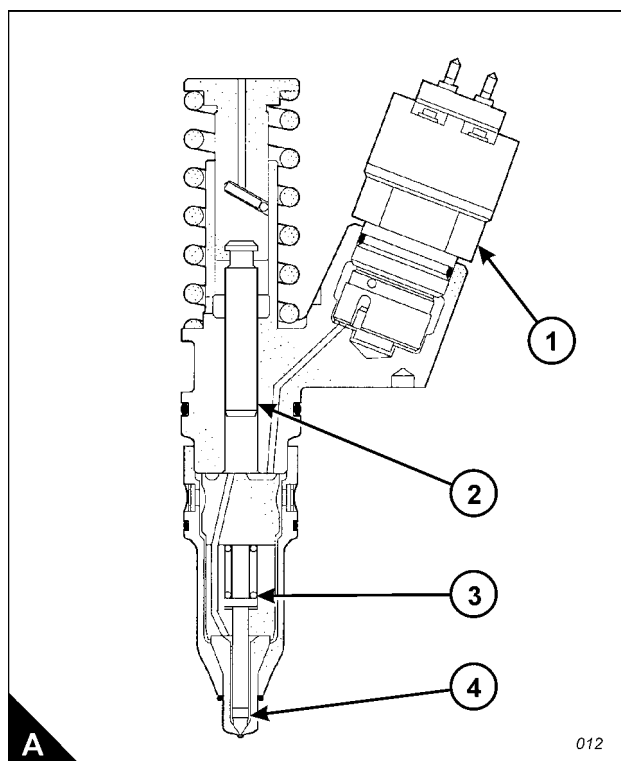
The fuel supply circuit used on the 2800 Series engines is a conventional design for engines fitted with unit fuel injectors. A fuel transfer pump, driven by the timing gears of the engine, is fitted behind the gear case on the left side of the engine. The fuel transfer pump draws fuel from the fuel tank. The fuel is filtered by the primary fuel filter before it enters the transfer pump. From the transfer pump, the fuel is filtered by the secondary fuel filter and is then supplied to the fuel gallery in the cylinder head. The fuel injectors draw fuel from the gallery and return the spill fuel to the same gallery. A pressure relief valve ensures that the pressure in the gallery is maintained and any excess fuel is returned to the fuel tank.

Each unit fuel injector is operated, through a rocker lever, by a lobe of the camshaft. This provides the force required to pressurize the fuel in the fuel injector. The camshaft has three lobes for each cylinder, the other two lobes operate the inlet and exhaust valves. The unit fuel injectors are fitted with a solenoid (A1) which is electronically controlled by the ECM (engine control module).

Low pressure fuel circulates through the body of the unit fuel injector and excess fuel is returned to the fuel gallery through a spill port. When the solenoid of the unit fuel injector is activated by a signal from the ECM, it closes the escape route for the fuel and the pressure increases in the fuel injector tip (A4).

Injection begins when the pressure in the tip reaches 34464 kPa (5,000 lb/in<sup>2</sup>). At this pressure the force applied by the spring (A3) is not sufficient to keep the nozzle closed. As the plunger (A2) moves through its full stroke, the pressure increases. When the correct amount of fuel has been injected, the ECM de-energises the solenoid. This opens the spill port and the reduction in pressure allows the spring (A3) to close the fuel injector nozzle. The high-pressure fuel which passes through the spill port returns to the fuel gallery.

During maintenance of the fuel system, clean thoroughly each component before it is removed or dismantled and fit suitable caps and plugs to all unions immediately after they have been disconnected.



## Electronic Fuel injector units

To remove and to fit

Operation 11-1

### Special requirements

Special tools			
Description	Part number	Description	Part number
Vacuum pump	GE50028	Brush	GE50022
Tube	GE50030	Brush	GE50023
Bottle	GE50029	Brush	GE50024

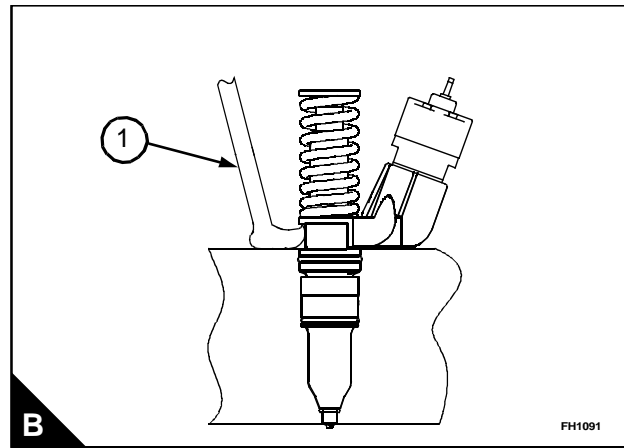
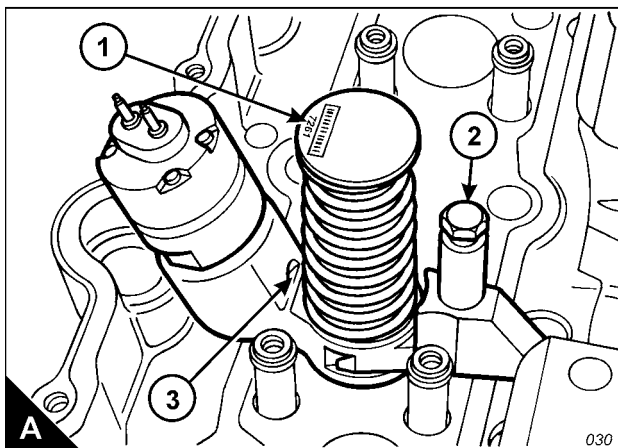
### To remove

**Warning!** The electrical circuit for the electronic fuel injector units operates on 110 volts. Do not work on the electronic fuel injector units unless the power supply to the ECM has been disconnected.

- 1 Remove the relevant rocker shaft assembly, see Operation 3-3.
- 2 Loosen the two nuts and remove the electrical connector from the fuel injector unit.
- 3 Mark the valve bridge pieces to assist during assembly, then remove them.
- 4 Remove the setscrew (A2) from the spacer and clamp which retain the fuel injector unit and use a suitable tool, (B1) to release the fuel injector unit from the cylinder head.

**Caution:** If more than one fuel injector unit is to be removed, make a note of the trim code (A1), a four-digit number adjacent to the bar code, and also the cylinder to which the fuel injector unit is fitted.

- 5 Remove the fuel injector unit, together with the spacer and clamp and put in clean storage.
- 6 Use the vacuum pump GE50028 together with the tube GE50030 and bottle GE50029 to remove any fuel that may be in the combustion chamber after removal of the electronic fuel injector unit.





**To fit**

**1** Clean thoroughly the bore of the fuel injector sleeve and cylinder head. Use the special brushes GE50022 GE50023 and GE50024 to remove carbon or dirt.

**2** Check the condition of the 'O' ring seals (B1 and B2); renew the seals if they are worn or damaged. Lubricate the 'O' ring seals with clean engine lubricating oil before the fuel injector unit is installed in the cylinder head.

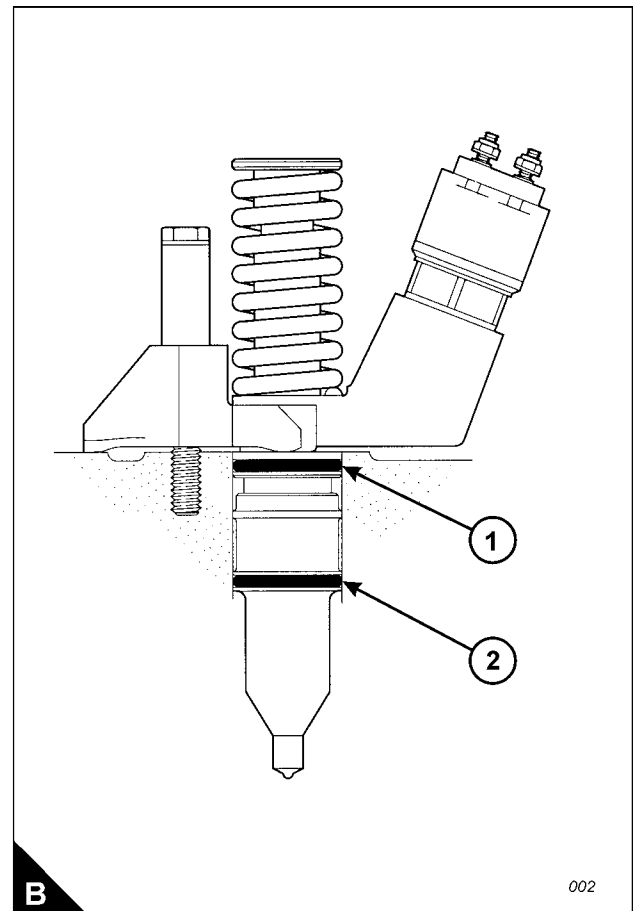
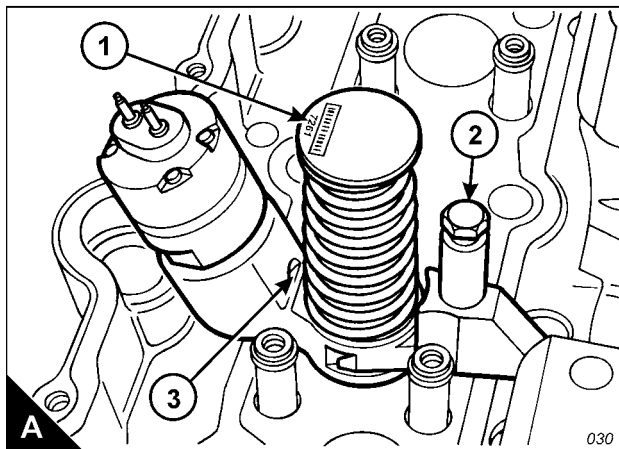
**Caution:** Fuel injector units must be fitted to their original positions or the information in the ECM will need to be updated.

**3** Fit the fuel injector unit to the cylinder head. Fit the clamp, spacer and setscrew. Tighten the setscrew (A2) to a torque of 47 Nm (35 lbf ft) 4,8 Kgf m.

**4** Fit the bridge pieces.

**5** Attach the electrical connector to the fuel injector unit and retain with the two nuts. Tighten the nuts to a torque of 2,5 Nm (22 lbf in) 0,25 kgf m.

**6** Fit the rocker shaft assembly, see Operation 3-3.



## To check and to adjust

## Operation 11-2

## Special requirements

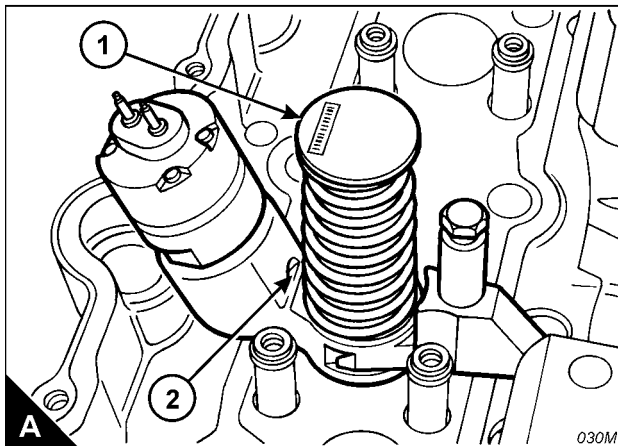
Special tools	
Description	Part number
Injector height gauge	CH11149

**Warning!** The electrical circuit for the fuel injector units operates on 110 volts. Do not work on the fuel injector units unless the power supply to the ECM has been disconnected.

**Note:** This operation should be performed at the same time as the operation to check the valve tappet clearances, see Operation 3-5.

- 1 With the rocker covers removed, set the number 1 piston to TDC (top dead centre) on its compression stroke, see Operation 8-1. Check/adjust the height dimensions for the fuel injectors of cylinders 3, 5 and 6.
- 2 Use the fuel injector setting gauge CH11149 to obtain the correct height for the fuel injector. The dimension to be measured is from the top of the unit fuel injector (A1) to the machined ledge on the fuel injector body (A2). This dimension should be  $78,0 \pm 0,2$  mm ( $3.07 \pm 0.01$  in). Loosen the lock nut and use the adjustment screw of the rocker lever to obtain the correct dimension. Tighten the lock nut to a torque of 55 Nm (41 lbf ft) 5,6 kgf m.
- 3 Remove the timing setscrew from the flywheel housing and rotate the flywheel by 360 degrees in the normal direction of engine rotation until the timing setscrew can be inserted into the threaded hole. This will put the number 1 piston at TDC in its exhaust stroke.
- 4 Check/adjust the height dimensions for the fuel injectors of cylinders 1, 2 and 4 as given in step 2.

When all adjustments have been made, remove the timing setscrew, fit the cover to the flywheel housing, fit the plug to the timing setscrew position and fit the rocker covers.



**Fuel priming pump**

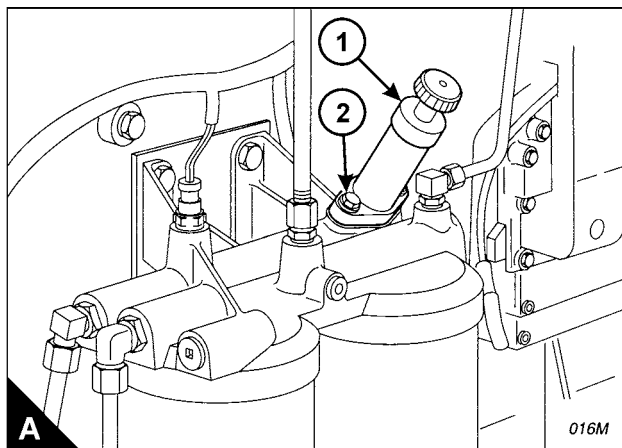
To remove and to fit

**Operation 11-3****To remove**

- 1 Remove two setscrews (A2) and remove the fuel priming pump (A1).

**To fit**

- 1 Inspect the gasket of the fuel priming pump; fit a new gasket if necessary.
- 2 Fit the fuel priming pump (A1) and retain with the two setscrews (A2).



## Fuel transfer pump

To remove and to fit

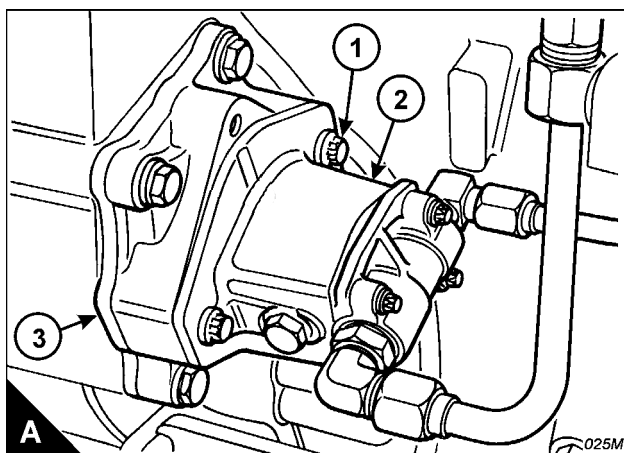
### Operation 11-4

#### To remove

- 1 Disconnect the fuel pipes from the fuel transfer pump (A2).
- 2 Ensure that plugs or caps are used to prevent contamination of the fuel system.
- 3 Remove the setscrews (A1) and withdraw the fuel transfer pump.

#### To fit

- 1 Check the condition of the 'O' ring on the fuel transfer pump, renew the 'O' ring if it is worn or damaged.
- 2 Ensure that the 'O' ring is fitted correctly to the fuel transfer pump. Apply a small amount of clean engine lubricating oil to the 'O' ring.
- 3 Fit the fuel transfer pump (A2) and retain with two setscrews (A1).
- 4 Remove the plugs or caps from the fuel pipe openings and connect the fuel pipes.
- 5 Eliminate air from the fuel system, see Operation 11-7.



**Drive for the fuel transfer pump**

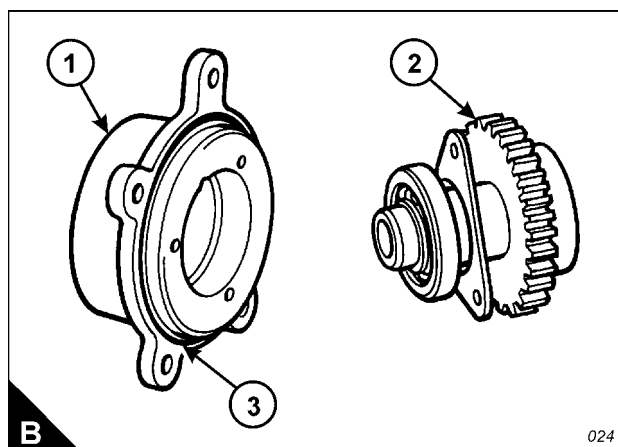
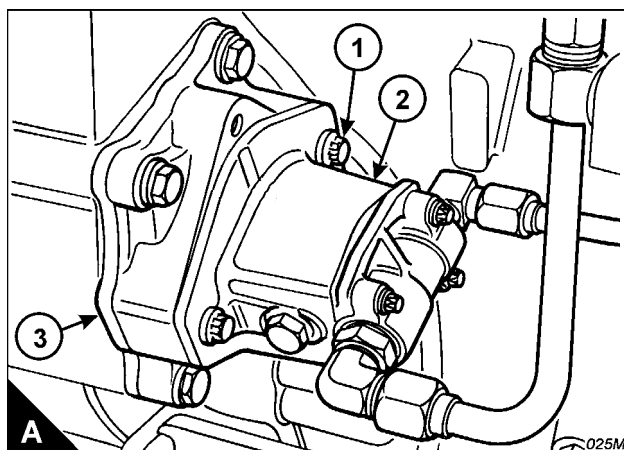
To remove and to fit

**Operation 11-5****To remove**

- 1 Remove the fuel transfer pump (A2), see Operation 11-4.
- 2 Remove four setscrews and washers (A1) and withdraw the assembly of the pump drive and housing (A3) from the gear case.
- 3 Remove the three setscrews from the housing (B1) and remove the assembly of the bearings and gear (B2) from the housing.
- 4 Remove the 'O' ring (B3) from the housing.
- 5 Inspect all components, renew any which are worn or damaged.

**To fit**

- 1 Fit the assembly of the bearings and gear (B2) into the pump drive housing (B1).
- 2 Retain the gear and bearings in the housing with the three setscrews.
- 3 Fit a new 'O' ring (B3) to the housing.
- 4 Insert carefully the assembly of the pump drive and pump drive housing into the gear case. Retain with four setscrews and washers.
- 5 Fit the fuel transfer pump, see Operation 11-4.



## Fuel filter header

To remove and to fit

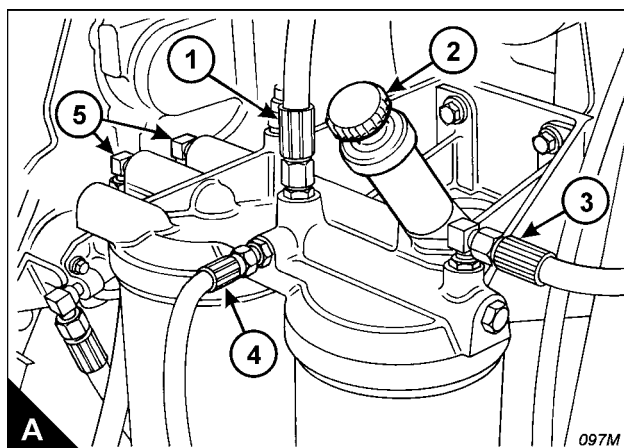
### Operation 11-6

#### To remove

- 1 Remove the fuel priming pump (A2), see Operation 11-3.
  - 2 Disconnect the fuel pipes (A1, A3, A4 and A5). Fit plugs or caps to all openings to prevent contamination of the fuel system.
  - 3 Remove the filter housings and elements from the fuel filter header.
- Warning!** Discard the used filter elements and 'O' ring in a safe place and in accordance with local regulations.
- 4 Remove the setscrews which retain the filter header on the crankcase.

#### To fit

- 1 Fit the filter header to the crankcase.
- 2 Remove any plugs or caps and connect the fuel pipes (A1, A3, A4 and A5).
- 3 Renew the fuel filter elements in the primary and secondary fuel filter canisters. Refer to the User's Handbook TPD 1516.
- 4 Fit the fuel priming pump, see Operation 11-3.
- 5 Eliminate air from the fuel system, see Operation 11-7.



## Low pressure fuel system

### How to eliminate air from the fuel system

### Operation 11-7

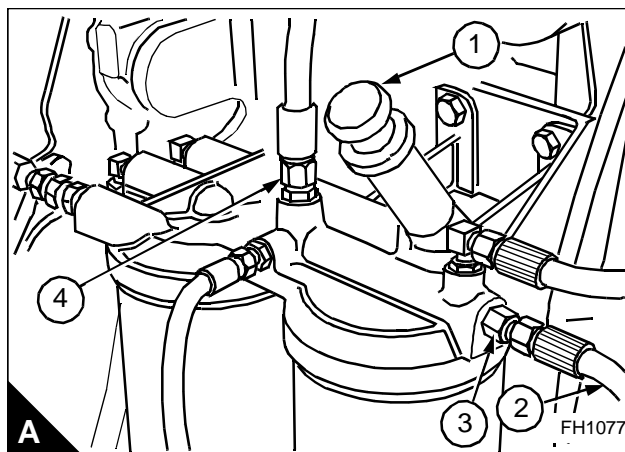
- 1 Position a suitable container below the fuel filters.
- 2 Connect the vent tube (A2) to the valve (A3).
- 3 Unlock and operate the hand priming pump (A1).
- 4 When fuel free from air comes from the vent tube remove the vent tube.
- 5 Loosen the union of the fuel return pipe (A4) and operate the hand priming pump.
- 6 When fuel free from air comes from the union tighten the union securely.
- 7 Lock the hand priming pump (A1) and remove the container.
- 8 Start the engine.

**Caution:** Do not crank the engine continuously for more than 30 seconds. Allow the starter motor to cool for two minutes before the engine is cranked again.

9 If the engine will not start, allow the starter motor to cool for 2 minutes. Continue to eliminate air from the fuel system if:

- The engine starts, but runs unevenly.
- The engine starts, but continues to misfire or smoke.

10 Run the engine with no load until it runs smoothly.



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# 12

## Cooling system

### General information

**Warning!** Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

The coolant system is under pressure. This allows the system to operate at a temperature higher than the boiling point of water and stops cavitation in the coolant pump.

In normal operation, the coolant pump directs most of the coolant through the oil cooler and into the cylinder block. The coolant circulates around the cylinder liners and is then directed into the cylinder head where it flows around the valves and passages for the exhaust gases. The coolant leaves the cylinder head at the front end and enters the thermostat housing.

When the engine is cold, the thermostats are closed and the coolant flow is directed back to the coolant pump. When the engine is at normal operating temperature, the thermostats open and the flow is directed to the top of the radiator. The coolant flows from the top to the bottom of the radiator and then returns to the coolant pump.

**Caution:** Only the approved coolant should be used. Refer to the User's Handbook TPD 1516.

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**Cooling system**

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**To inspect**

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**Operation 12-1**

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**Warnings!**

- *Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.*
- *On a hot engine release the filler cap carefully as the system will be under pressure.*

Inspect visually the cooling system before any tests are performed.

**Notes:**

- A small amount of leakage of coolant across the surface of the face seal in the water pump is normal. Its purpose is to provide lubrication for the seal.
  - There is a hole in the water pump body to allow coolant to drain. Small amounts of coolant may be seen to leak from time to time from the drain hole during the engine operation cycle.
  - Signs of a small leakage through the drain hole are not an indication that the pump is faulty. Marks from the coolant or drops of coolant from the hole, indicate normal operation of the pump.
- 1 Check the coolant level in the cooling system.
  - 2 Check for leaks in the system.
  - 3 Ensure that the air flow through the radiator and charge cooler is not restricted. Check for damaged fins in the radiator and also for large deposits of dirt or debris.
  - 4 Inspect the drive belts for the fan.
  - 5 Check for damage to the fan blades.
  - 6 Check for air or combustion gas in the cooling system.
  - 7 Inspect the filler cap and check the surface which the filler cap seals against. This surface must be clean.

## Leakage test

## Operation 12-2

## Special requirements

Special tools	
Description	Part number
Pressurizing pump	GE50031

**Warning!** On a hot engine release the filler cap carefully as the system will be under pressure. Cooling system conditioner contains alkali. Avoid contact with skin and eyes.

- 1 When the engine is cool, loosen the filler cap slowly to relieve any pressure then remove the filler cap from the radiator.
- 2 Ensure that the coolant is at the correct level.
- 3 Attach the pressurizing pump GE50031 to the radiator and apply pressure until the reading on the gauge is 20 kPa (3 lb/in<sup>2</sup>) more than the pressure given on the filler cap.
- 4 Check the radiator for leakage.
- 5 Check all connection points and hoses for leakage.

The cooling system is free from leaks if you do not see any external leakage and the reading remains constant for at least five minutes. If the reading on the gauge goes down and there is no external leakage, the cooling system must be leaking internally. Make repairs as necessary.

The cooling system is free from leaks if you do not see any external leakage and the pressure on the gauge remains constant for five minutes. If the pressure has dropped on the gauge and there is no external leakage, the cooling system must have internal leak. Make repairs as necessary.

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**Coolant filler cap**

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To test

**Operation 12-3**

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**Special requirements**

Special tools	
Description	Part number
Pressurizing pump	GE50031

**Warning!** On a hot engine release the filler cap carefully as the system will be under pressure. Cooling system conditioner contains alkali. Avoid contact with skin and eyes.

- 1 When the engine is cool, loosen the filler cap slowly to relieve any pressure then remove the filler cap from the radiator.
- 2 Carefully inspect the filler cap. Check for damage to the seals and to the contact surface. Check the filler cap, the seal and the surface for seal, ensure that they are free from deposits. Any deposits or other material that is found on these items must be removed.
- 3 Fit the filler cap to the pressurizing pump GE50031.
- 4 Apply pressure and check the gauge for the exact pressure which opens the filler cap.
- 5 Compare the reading on the gauge with the correct pressure which should open the filler cap, this figure is given on the filler cap.
- 6 Renew the filler cap if it is defective.

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**Radiator**

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**To remove and to fit**

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**Operation 12-4**

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**To remove**

**Note:** Use suitable lift equipment in order to remove the components.

- 1 Drain the coolant into a suitable container.
- 2 Remove the air duct from the air charge cooler to the air inlet elbow.
- 3 Remove the coolant pipe from the thermostat housing to the top of the radiator.
- 4 Remove the fan guards.
- 5 Remove the air duct from the turbocharger to the base of the charge air cooler.
- 6 Remove the fuel pipes to the fuel cooler.
- 7 Remove the coolant pipe from the coolant pump elbow to the radiator.
- 8 Remove fasteners which retain the radiator to its base frame.

**To fit**

**Note:** Use suitable lift equipment in order to fit the components.

- 1 Fit the radiator to its base frame.
- 2 Fit the coolant pipe from the coolant pump elbow to the radiator.
- 3 Fit the fuel cooler pipe.
- 4 Fit the air duct from the turbocharger to the base of the charge air cooler.
- 5 Fit the fan guards.
- 6 Fit the coolant pipe from the thermostat housing to the top of the radiator.
- 7 Fit the air duct from the charge air cooler to the air inlet elbow.
- 8 Fill the radiator with the correct coolant mixture. Refer to the User's Handbook TPD 1516.
- 9 Operate the engine until the engine is at normal temperature and check for leaks.

## Fan

To remove and to fit

## Operation 12-5

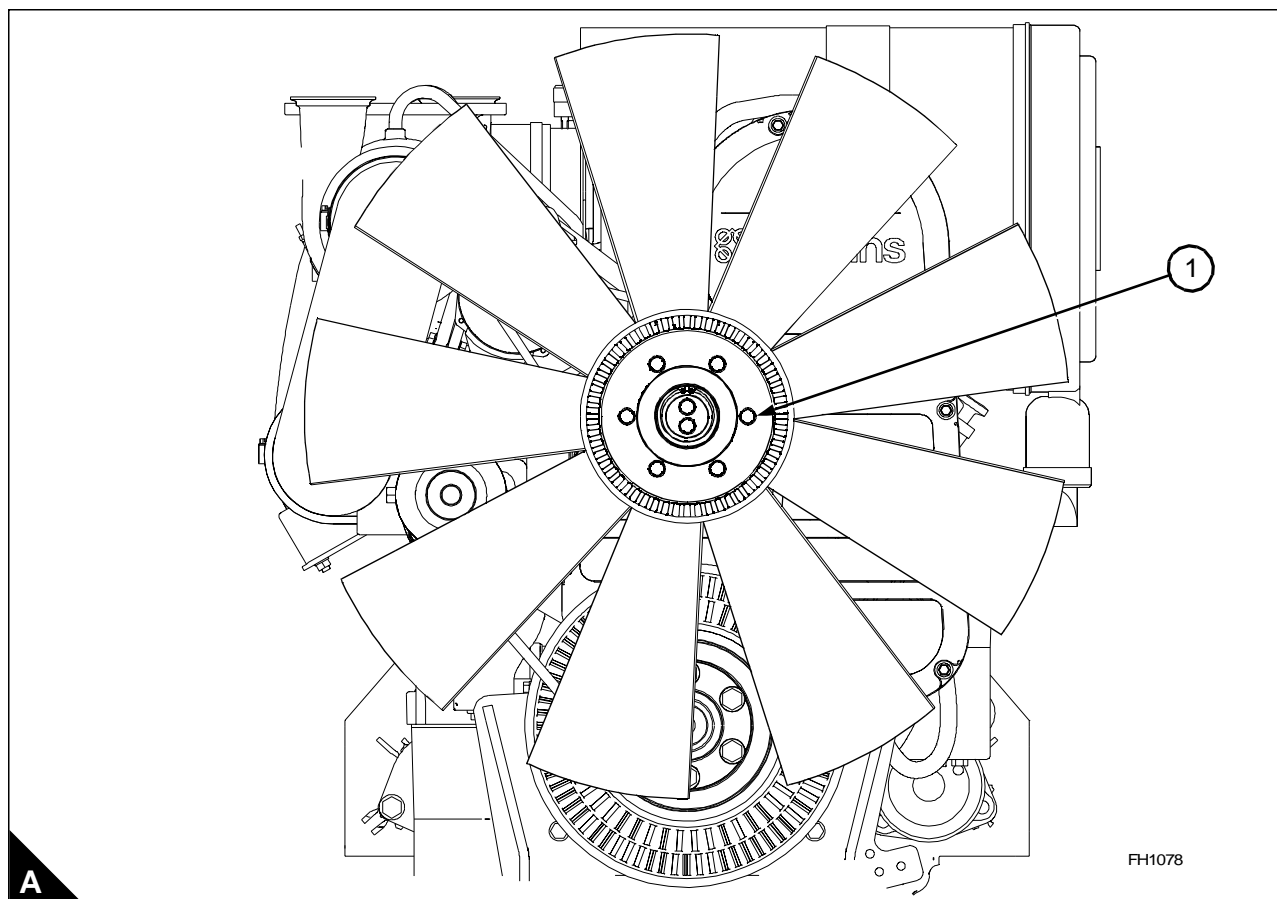
## To remove

1 Switch off the engine and disconnect the electrical power supply.

2 Remove the fan guards.

**Caution:** Ensure that the radiator is protected when the fan is removed.

3 Remove the setscrews (A1) which retain the fan on the hub and remove the fan.



## To fit

1 Align the fan to the hub and fit the six setscrews (A1). Tighten the setscrews to torque of 46 Nm (34 lbf ft) 4,6 kgf m.

2 Fit the fan guards.

3 Connect the electrical power supply.

**Fan drive assembly**

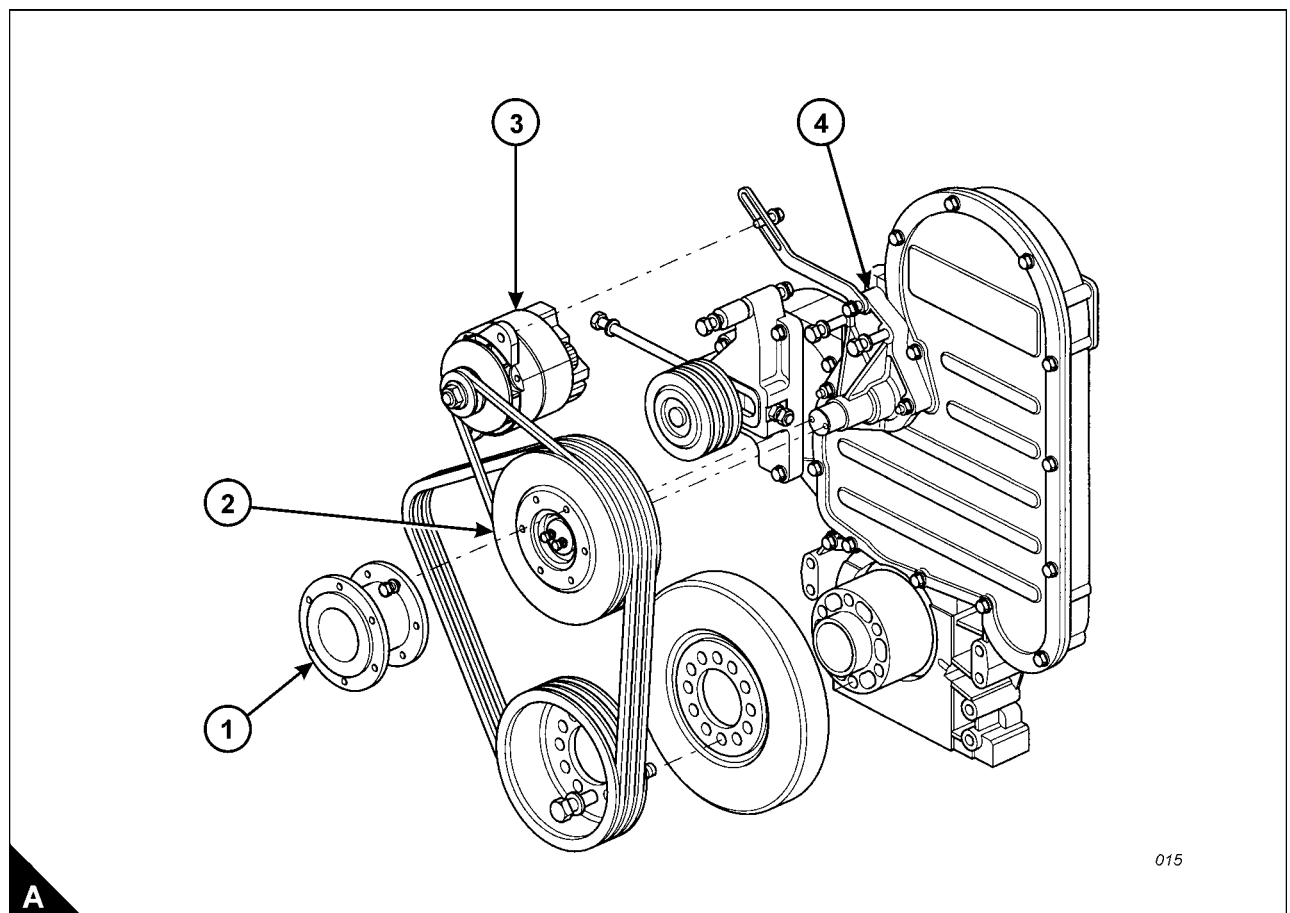
To remove and to fit

**Operation 12-6****To remove**

- 1 Remove the fan, Operation 12-5.
- 2 Remove the hub (A1).
- 3 Remove the alternator (A3), see Operation 14-2.
- 4 Release the tension on the fan drive belts and remove the belts.
- 5 Remove the two setscrews and cap which retain the pulley (A2) and withdraw the pulley complete with bearing.
- 6 Remove the two nuts and two setscrews which retain the fan bearing housing (A4) and remove the housing.

**To fit**

- 1 Fit the fan bearing housing (A4).
- 2 Fit the pulley (A2) and retain with the cap and two setscrews. Tighten the setscrews to a torque of 24 Nm (18 lbf ft).
- 3 Fit the fan drive belts and adjust the tension, see Operation 12-7.
- 4 Fit the alternator (A3), see Operation 14-2. Fit the alternator belt and adjust the tension, see Operation 14-3.
- 5 Fit the hub (A1).
- 6 Fit the fan, see Operation 12-5.

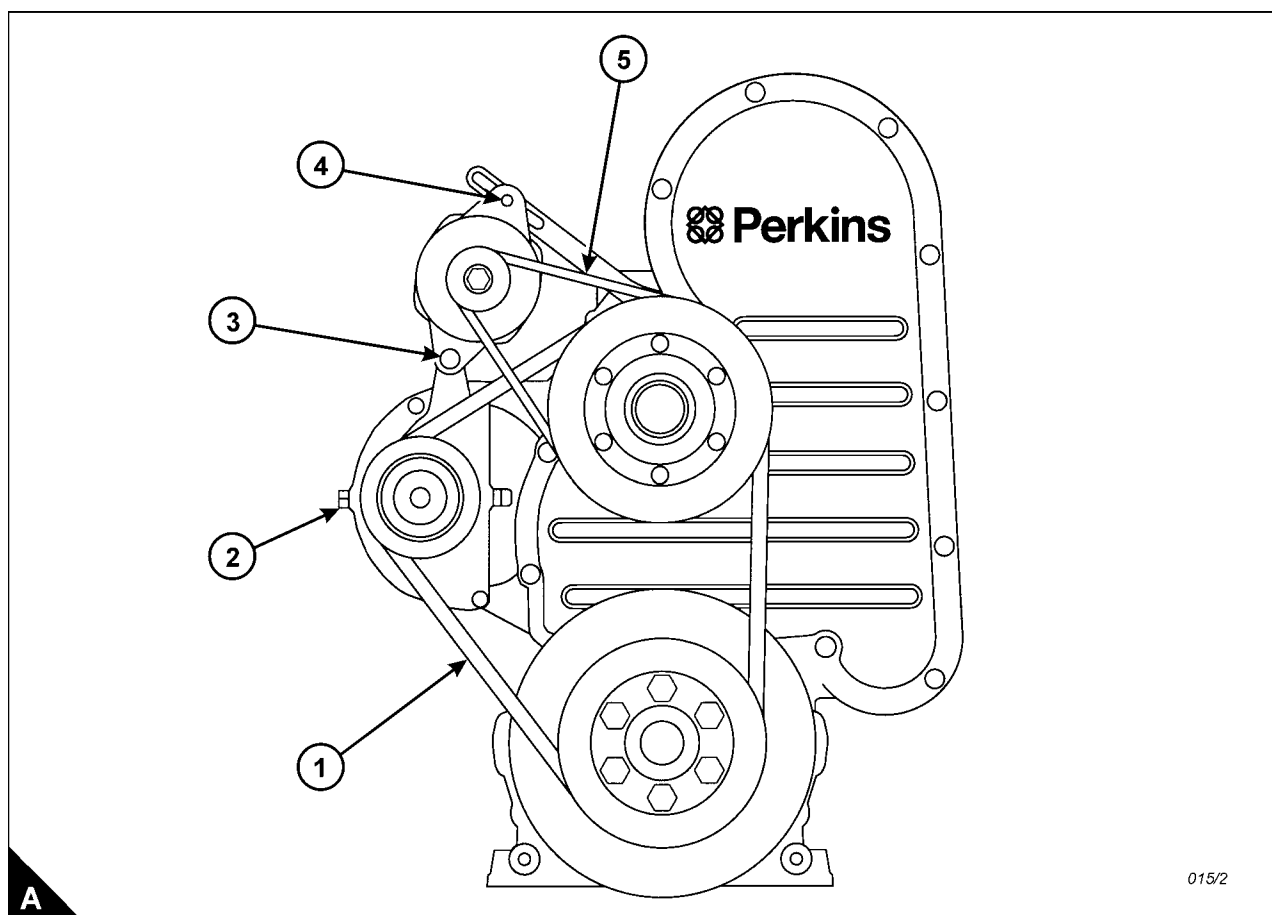


## Fan drive belts

## To check and to adjust the tension

## Operation 12-7

- 1 Remove the fan guards.
- 2 Use a Borroughs belt tension gauge to check the tension at the position shown (A1). It should be 714 N, (160 lbf) 72 kgf. To adjust the tension, proceed as follows:  
**Caution:** A fan belt must be adjusted if the tension is 446 N (100lbf) 45 kgf or below.
- 3 Loosen the lock nuts on the adjustment setscrew (A2), loosen the large lock nut on the belt tensioner and turn the adjustment setscrew (A2) until the correct tension is obtained. Tighten the large lock nut to 280 Nm (207 lbf ft) 28,5 kgf m. Check the tension of the belts again and adjust if necessary.
- 4 If the tension is correct, slacken the adjustment setscrew (A2) just enough to release its tension, then tighten its lock nuts.
- 5 Fit the fan guards and run the engine for 15 minutes. Remove the guards and check again the tension.
- 6 For new fan belts, set the tension to 714 N (160 lbf) 72 kgf. After the engine has been run for 15 minutes, check the tension and adjust it to 714 N (160 lbf) 72 kgf.



- 7 When the correct tension is obtained, fit the fan guards.



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To renew

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Operation 12-8

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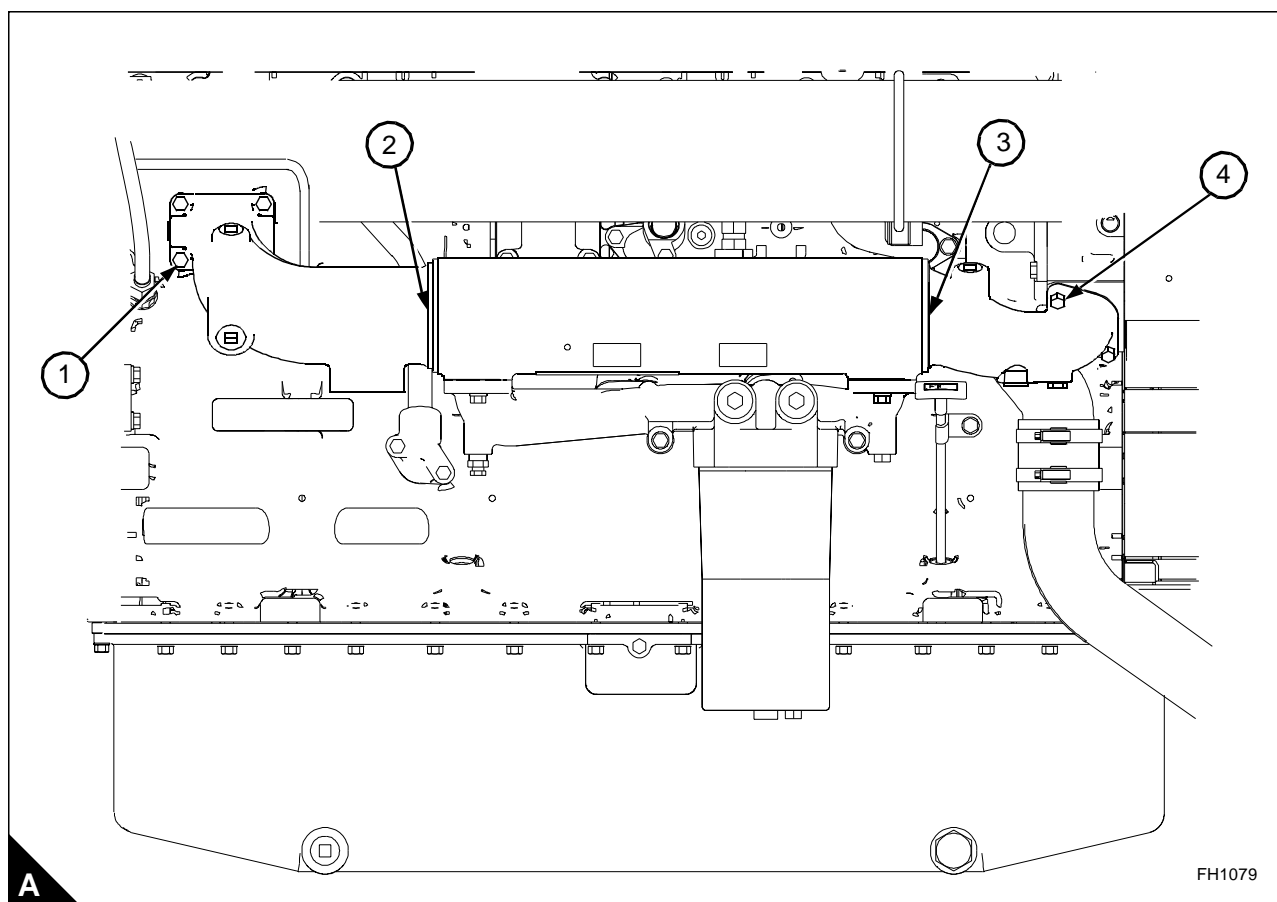
- 1 Remove the fan, see Operation 12-5.
- 2 Loosen the belt tensioner and remove the old belts. Ensure that the grooves of the pulley are free from grease and dirt and fit a new set of belts.
- 3 Fit the fan, see Operation 12-5.
- 4 Adjust the fan belts to the correct tension, see Operation 12-7.

**Engine oil cooler**

To remove

**Operation 12-9****To remove**

- 1 Drain the coolant from the engine.
- 2 Position a suitable container below the oil cooler.
- 3 Remove the oil filter element, see Operation 10-1.
- 4 Remove the oil filter head, see Operation 10-2.
- 5 Make temporary marks on the body (A2) and the (A3) to align on assembly.
- 6 Remove the setscrews (A1) and (A4).
- 7 Remove the oil cooler from the engine.



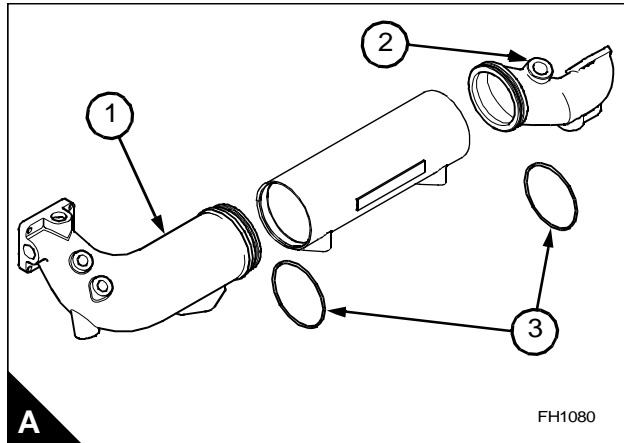
## To dismantle and to assemble

## Operation 12-10

**To remove**

- 1 Remove the elbow (A1) from the cooler body and remove the end (A2) from the cooler body.
- 2 Remove the 'O' ring (A3) and discard,
- 3 Clean the core tubes of the oil cooler with a 3,81 mm (0.150 in) diameter rod.

**Note:** The matrix is not removable from the housing.

**To fit**

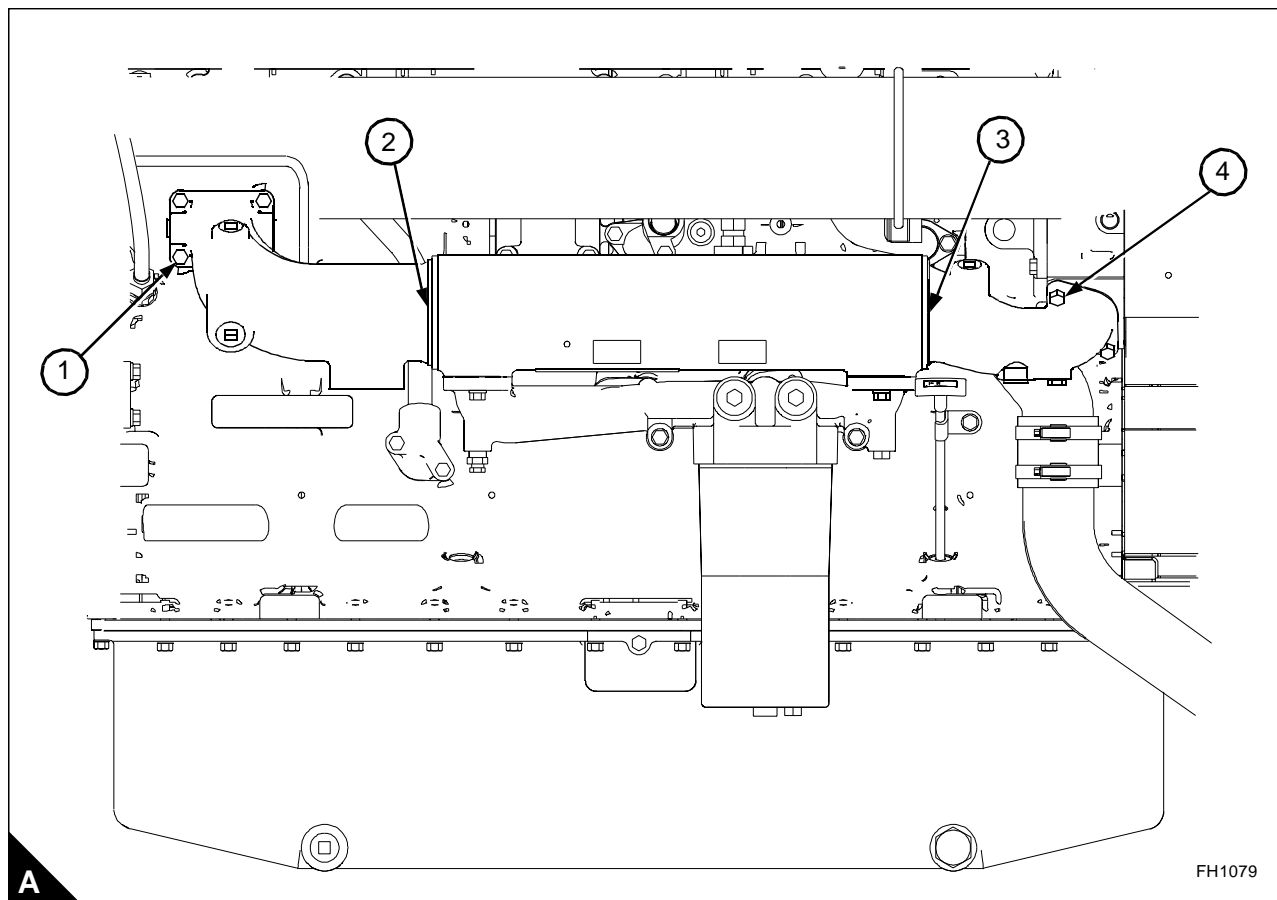
Ensure that all components are clean and dry.

- 1 Apply clean engine lubricating oil to the new 'O' ring (A3). Fit new 'O' ring to (A1) and (A2).
- 2 Fit (A1) and (A2) into the body. Check that they are aligned correctly.

To fit

## Operation 12-11

- 1 Align the oil cooler assembly with the new seals to the engine and loosely fit the setscrews (A1) and (A4).

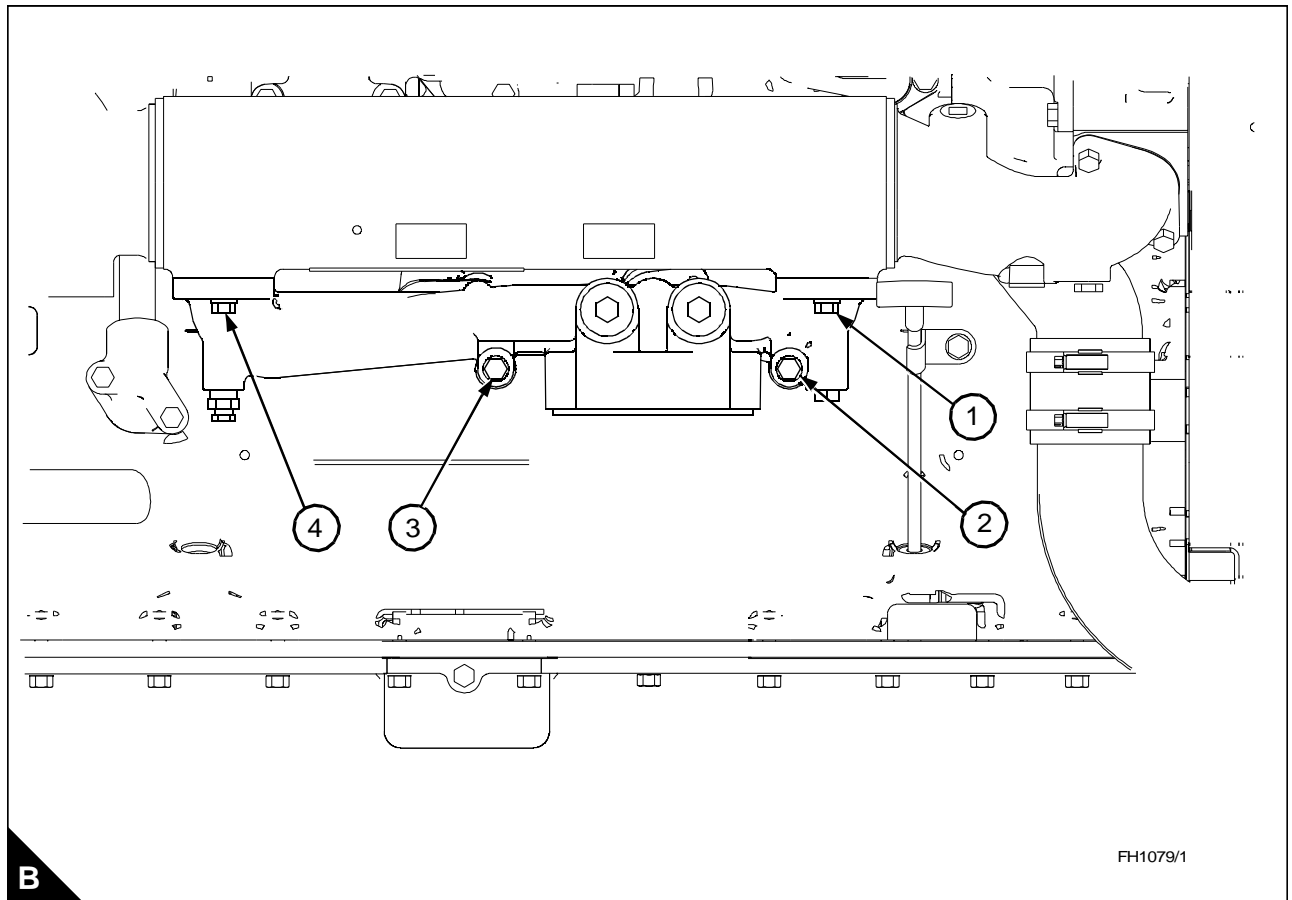


**Note:** The oil cooler and oil filter head must be installed together in order to align both parts to the engine.

- 2 Check the 'O' ring for the oil filter head and renew if necessary.

*Continued*

**3** Align the oil filter head to the oil cooler. Loosely fit the setscrews (B1) and (B4). Loosely fit the setscrews (B2) and (B3).



**4** Connect the oil supply pipe.

**5** Tighten all the setscrews to 55 Nm (40 lbf ft) 5,6 kgf m, and the turbocharger oil supply pipe securely.

**6** Fit the oil filter element, see Operation 10-1.

**7** Check the amount of lubricating oil in the sump. Add lubricating oil of the correct grade, if necessary. Refer to the User's Handbook TPD 1516.

**8** Fill the cooling system with the correct coolant mixture. Refer to the User's Handbook TPD 1516.

## Thermostats and thermostat housing

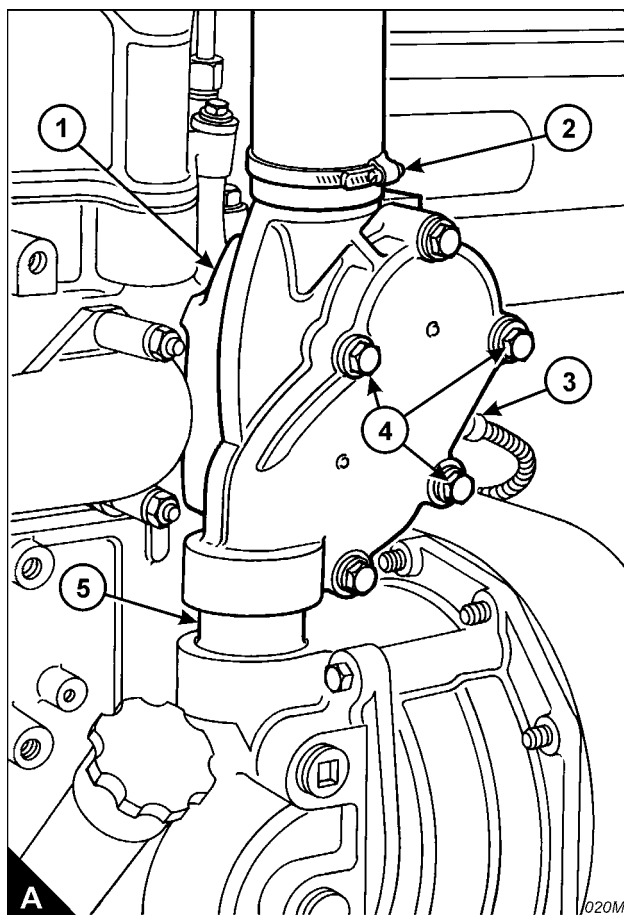
To remove

Operation 12-12

### To remove

- 1 Drain the coolant until the level is below the thermostat housing (A1).
- 2 Disconnect the cable (A3) from the coolant temperature sensor.
- 3 Release the hose clips (A2) and disconnect the pipe and hose from the top of the unit.
- 4 If the thermostats are to be removed, loosen all five setscrews of the thermostat housing; then remove fully the three setscrews (A4) which retain the thermostat housing on the cylinder head. If the thermostat housing is to be removed without access to the thermostats, do not loosen the five setscrews; remove only the three retaining setscrews (A4).
- 5 Lift carefully the assembly to separate it from the coolant bobbin (A5) at its base.

**Note:** If relevant, remove the two short setscrews which remain, separate the two halves of the assembly and remove the thermostats.



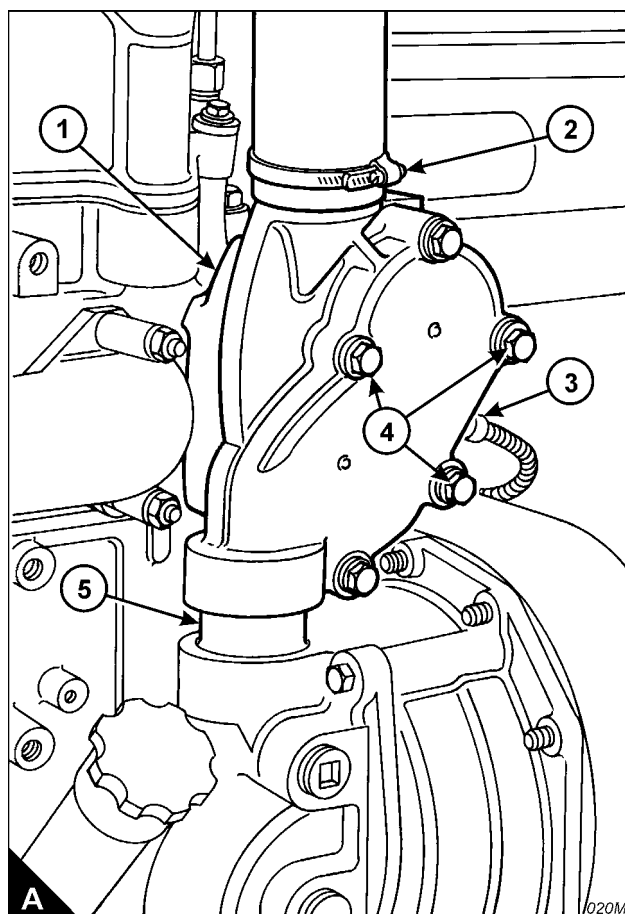
## To fit

## Operation 12-13

**Warning!** Take care during removal of the filler cap as the coolant system will be under pressure.

**Note:** If the thermostat housing has not been dismantled, continue from step 3.

- 1 Clean thoroughly both parts of the assembly and check the condition of the lip-type seals. Renew the seals if they are worn or damaged.
- 2 Fit the new thermostats. Ensure that the new thermostats are fitted correctly. Fit a new 'O' ring type seal to the groove in the thermostat housing, assemble the two halves of the unit and retain with the two short setscrews.
- 3 Ensure that the location face on the cylinder head is clean. Fit new seals to the coolant bobbin (A5) which fits into the base of the unit and lubricate the seals with a small amount of rubber lubricant. Fit a new 'O' ring to the groove in the location face of the housing and fit the assembly over the coolant bobbin. Fit the three setscrews (A4) which retain the thermostat housing on the cylinder head and tighten all five setscrews to a torque of 47 Nm (35 lbf ft) 4,7 kgf m.
- 4 Connect the hose to the top of the housing and tighten the hose clip.
- 5 Connect the cable (A3) to the coolant temperature sensor.
- 6 Fill the coolant system to the correct level with the approved coolant mixture, refer to the User's Hand Book 1516E1.
- 7 Operate the engine until the coolant is at the normal temperature and check for leaks. Stop the engine, check the coolant level and, if necessary, add extra coolant.



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To test the thermostats

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Operation 12-14

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**Warning!** Use care during this operation to avoid serious injury from the hot fluid.

- 1 Remove the thermostats from the engine.
- 2 Heat coolant in a suitable container until the temperature is 98 °C (208 °F). Stir the water to ensure that the temperature is consistent within the container.
- 3 Suspend the thermostat in the container of water. The thermostat must be below the surface of the coolant and it must be away from the sides and the bottom of the container.
- 4 Ensure that the water is maintained at the correct temperature for ten minutes.
- 5 After ten minutes, remove the thermostat. Immediately check the distance that the thermostat has opened. It must be a minimum of 10,4 mm (0.41 in). If the distance is less, renew the thermostat.



## Coolant temperature sensor

To test

Operation 12-15

### Special requirements

Special tools	
Description	Part number
Thermometer	GE50032

Check the accuracy of the coolant temperature sensor (A2) if one of these conditions exist:

The engine runs at a temperature that is too hot, but a normal temperature is indicated. A loss of coolant is found.

The engine runs at a normal temperature, but a hot temperature is indicated. No loss of coolant is found.

**Note:** The coolant temperature can be read on the display screen of the electronic service tool.

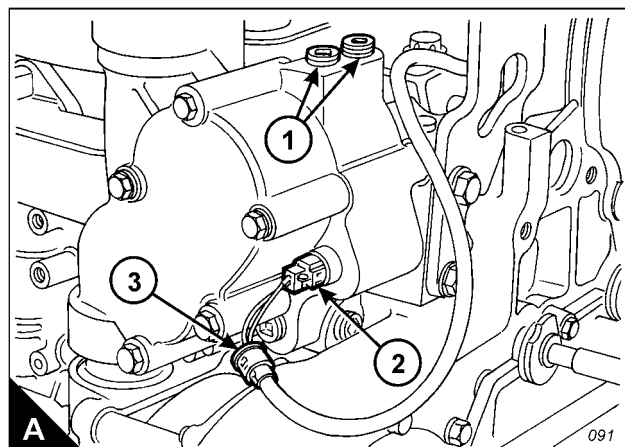
**Warning!** On a hot engine release the filler cap carefully as the system will be under pressure.

- 1 When the engine is cool, release the coolant filler cap to relieve any pressure.
- 2 Remove one of the two plugs (A1) and install the thermometer GE50032. A temperature indicator of known accuracy can also be used for this test. Tighten again the coolant filler cap.
- 3 Operate the engine until the engine is at correct temperature range for the test thermometer.
- 4 If necessary, place a cover over part of the radiator to cause a restriction of the coolant flow. The reading on the coolant temperature indicator should match with the test thermometer within the tolerance range of the coolant temperature indicator.

Pointer position	Test thermometer °C	Test thermometer °F
1	65 to 77	150 to 170
2	99 to 103	210 to 218

**Caution:** If a cover was used over part of the radiator ensure that is removed on completion of the test.

- 5 If the temperature sensor is renewed, do not attempt to disconnect the leads from the unit. Disconnect the unit at the connection shown (A3).



**Coolant pump**

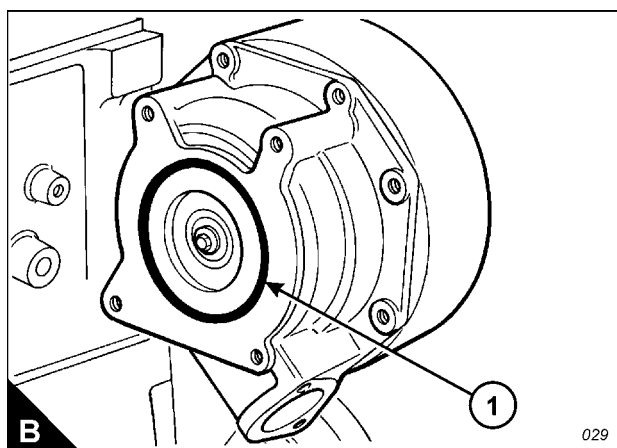
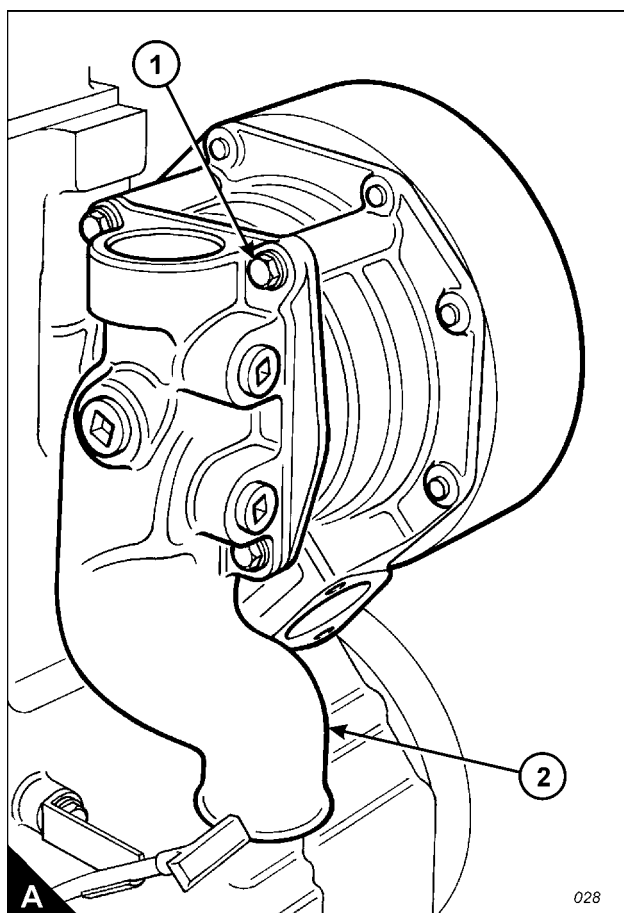
To remove and to fit

**Operation 12-16****To remove**

- 1 Drain the coolant from the engine into a suitable container for storage or disposal.
- 2 Remove the thermostat housing, see Operation 12-12.
- 3 Remove the oil cooler, see Operation 12-9.
- 4 Remove four setscrews (A1) and the elbow (A2).
- 5 Check the condition of the 'O' ring (B1), discard the seal if it is worn or damaged. Remove the setscrews from the gear case cover and the coolant pump and remove the coolant pump.

**To fit**

- 1 Fit the coolant pump to the gear case, ensure that the gear engages correctly. Tighten the setscrews.
- 2 If necessary, fit a new 'O' ring (B1). Fit the elbow (A2) and retain with four setscrews (A1).
- 3 Fit the oil cooler, see Operation 12-9.
- 4 Fit the thermostat housing, see Operation 12-12.
- 5 Fill the coolant system to the correct level with the specified coolant mixture. Refer to the User's Handbook TPD 1516.



**Notes:**

- The coolant pump seal can be renewed without removal of the coolant pump from the engine.
- Intermittent leakage of a small amount of coolant from the hole in the coolant pump housing is not an indication of a coolant pump seal failure. This is required to provide lubrication for the seal. Renew the coolant pump seal only if a large amount of leakage or a constant flow of coolant is seen to drain from the coolant pump housing.
- Service exchange coolant pumps can be obtained from your Perkins dealer/distributor.

**To dismantle**

1 Remove the setscrew (A15) and washer (A14). Use a suitable puller to remove the impeller (A11) from the shaft (A16). Ensure that the impeller does not become damaged during this operation.

2 Remove the spring and seal (A13) from the shaft.

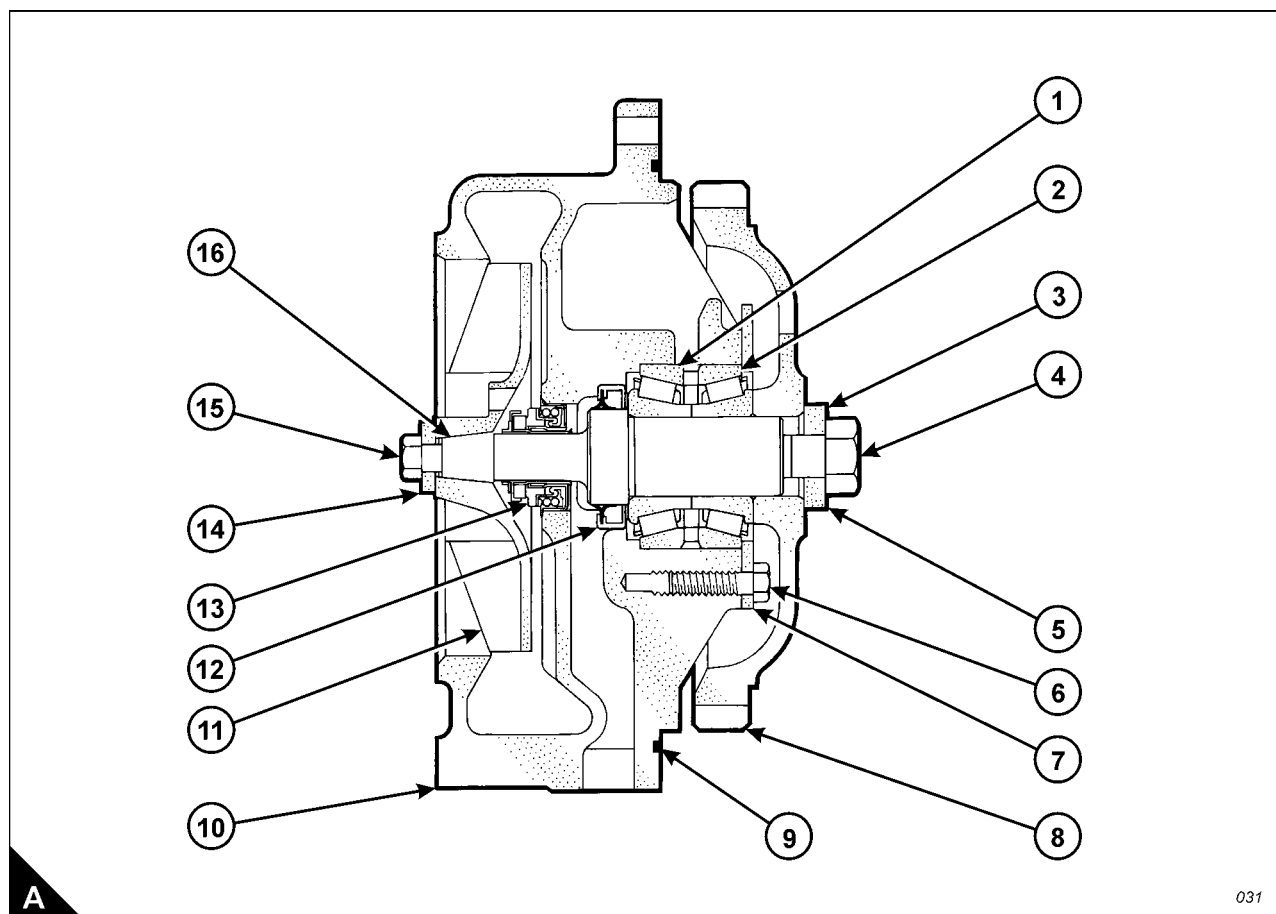
**Note:** The coolant pumps of certain engines may not have a spring fitted at this position.

3 Remove the four setscrews (A6) from the retainer (A7) and remove the 'O' ring seal (A9) from the housing (A10).

4 Remove the gear and shaft assembly (A8). Remove the setscrew (A4) and retainers (A3 and A7) from the shaft assembly.

5 Use a press to remove the shaft (A16) from the gear. Remove the bearing (A1), the spacer if fitted, and second bearing (A12) from the shaft.

6 Remove the lip-type seal (A12) from the housing.



## To assemble

- 1 Ensure that the shaft and the seal counter bore in the pump housing are clean.
- 2 Fit the bearing (A1), the spacer if relevant, and the second bearing (A2) to the shaft (A16).
- 3 Fit the retainer (A7) and gear (A8) to the shaft assembly. Fit the second retainer (A3) and the setscrew (A4).
- 4 Fit a new lip-type seal (A12) into the housing (A10). The seal must be fitted with the lip toward the inside of the housing. Apply a small amount of clean engine lubricating oil to the lip of the seal.
- 5 Fit a new 'O' ring (A9) to the housing.
- 6 Install the gear and shaft assembly in the housing. Fit the setscrews (A6) which hold the retainer (A7) to the housing.

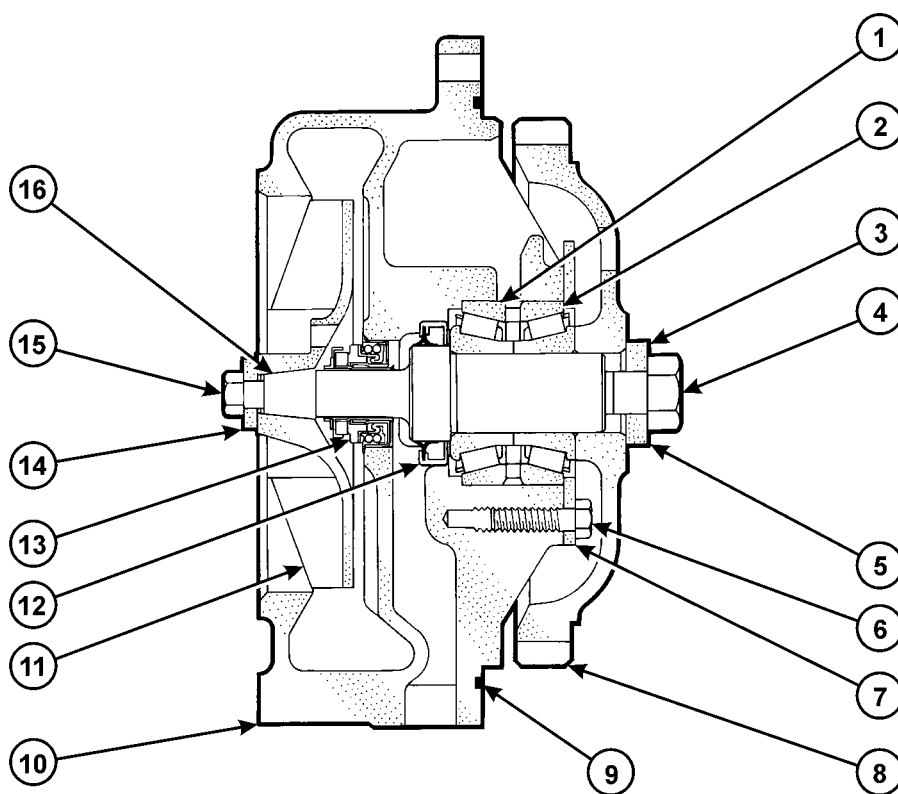
**Caution:** Do not allow grease or oil to contact the faces of the seal. Do not stretch the seal during installation.

**Note:** The carbon seal assembly (A13) must rotate with the coolant pump shaft when it is installed. Use clean water as a lubricant for assistance during installation.

- 7 Separate the spring from the seal assembly (A13). Use hand pressure to install the seal on the shaft (A16). Push the seal onto the shaft until the seal faces make light contact. Fit the spring to the shaft.

- 8 Fit the impeller (A11) to the shaft and retain with the washer (A14) and setscrew (A15). Tighten the setscrew to a torque of 39 Nm (28 lbf ft) 3,9 kgf m.

- 9 Fit the coolant pump, see Operation 12-16.



# 13

## Flywheel and housing

### General information

**Warning!** Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

The steel flywheel is fitted with a hardened starter ring. The flywheel is fastened securely to the rear face of the crankshaft by a clamp ring and 12 setscrews.

A dowel ensures that, when the flywheel is fitted, the timing marks on the flywheel are in the correct relationship to the crankshaft.

The flywheel housing is fitted on the crankcase by two dowels and 24 setscrews and washers. The electric starter motor is mounted on the left side of the flywheel housing and a facility is provided on the right side to set the engine to TDC on number one or number six piston.

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**Flywheel**

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**To remove and to fit**

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**Operation 13-1**

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**To remove**

**1** Remove two of the flywheel setscrews from horizontally opposite sides of the flywheel and insert two suitable guide studs.

**Note:** Use suitable lift equipment in order to remove the flywheel. The weight of the flywheel is approximately 56 kg (123 lb).

**2** Remove the setscrews which remain and remove the flywheel from the crankshaft. Use suitable lift equipment in order to remove the flywheel. The weight of the flywheel is approximately 56 kg (123 lb).

**3** Remove the flywheel and remove the guide studs.

**4** Remove the gear ring from the flywheel if necessary.

**To fit**

**1** If the gear ring has been removed, heat the ring in an oven to a maximum temperature of 315 °C (600 °F) and fit it to the flywheel. Ensure that the gear ring is fully seated on the flywheel.

**Note:** The gear ring must be fitted with the chamfer on the gear teeth toward the starter motor pinion.

**2** Fit suitable guide studs to setscrew holes at horizontally opposite sides of the flywheel. Ensure that the dowel is fitted in the end of the crankshaft.

**3** Use suitable lift equipment in order to fit the flywheel. Ensure and that the flywheel is correctly aligned with the dowel.

**4** Remove the sling and slide the flywheel up to the crankshaft.

**5** Apply clean engine lubricating oil to the threads of the setscrew which retain the flywheel and fit 10 of the setscrews. Remove the guide studs and fit the two setscrews which remain. Tighten the setscrews to a torque of 270 Nm (200 lbf ft) 27,5 kgf m.

## Flywheel housing

To remove and to fit

Operation 13-2

### Special requirements

Consumable products	
Description	Part number
Liquid gasket	CH10879

### To remove

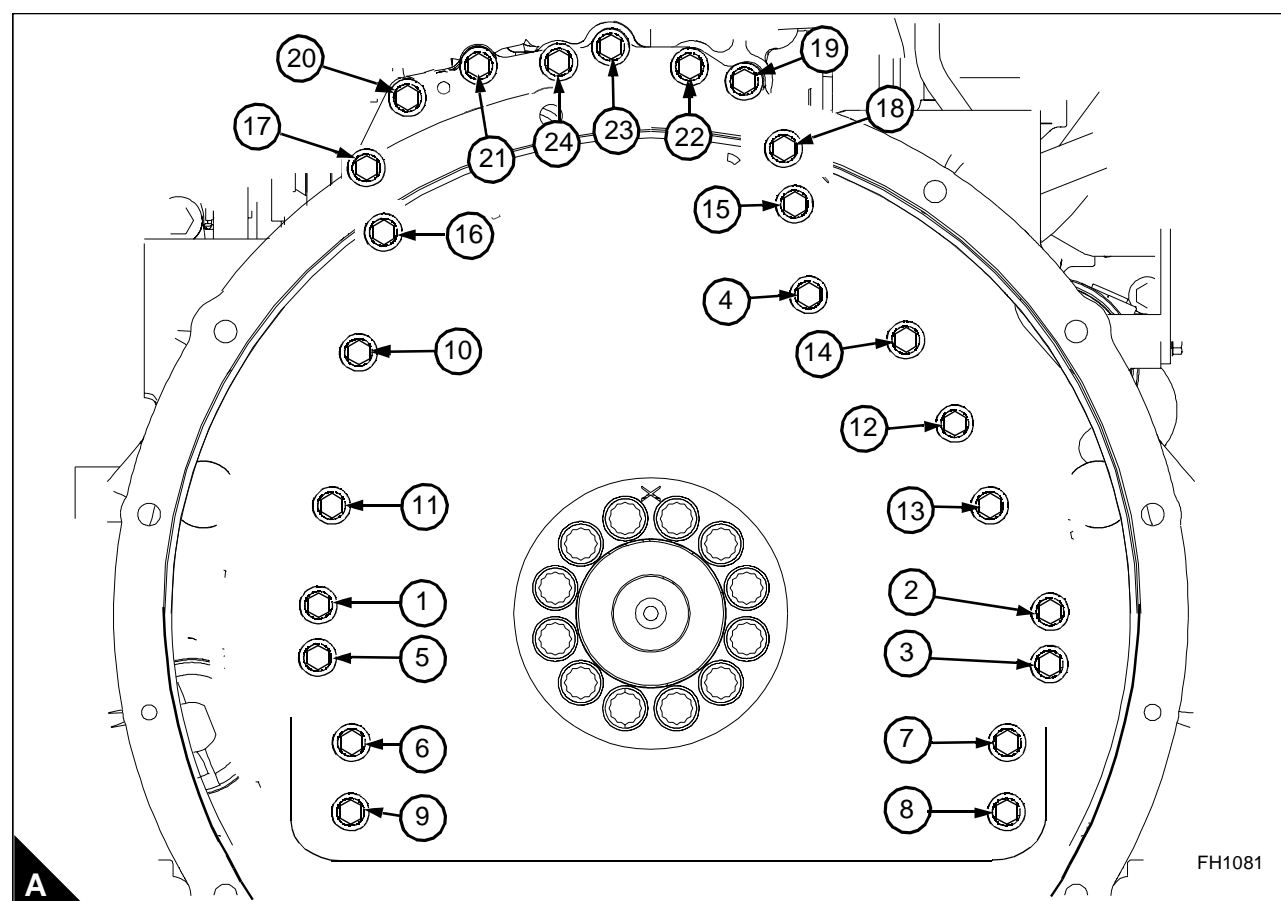
- 1 Remove the flywheel, see Operation 13-1.
- 2 Remove the crankshaft rear seal and wear sleeve, see Operation 5-3.
- 3 Remove the starter motor, see Operation 14-1.
- 4 Remove the sump, see Operation 10-5.

**Note:** Use suitable lift equipment in order to support the flywheel housing.

- 5 Remove the setscrews (A1 to A24) which retain it.

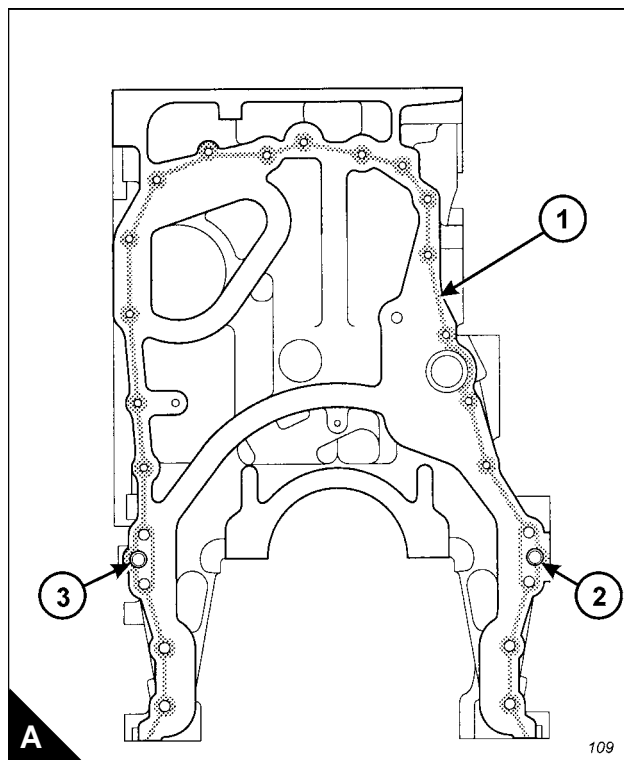
**Note:** The setscrews which retain the flywheel housing are of two different sizes. Make a note of their positions to ensure that they are fitted correctly.

- 6 Remove the flywheel housing from the dowels in the crankcase. The weight of the flywheel housing is approximately 83 kg (183 lb).



**To fit**

- 1 Clean thoroughly the contact surfaces of the crankcase and flywheel housing.
- 2 Fit the two dowels (A2) and (A3) if they have been removed from the crankcase. They must protrude from the crankcase by 19,1 +/- 0,5 mm (0.75 +/- 0.02 in).



- 3 Apply a bead of liquid gasket CH10879 to the area shown (A1).

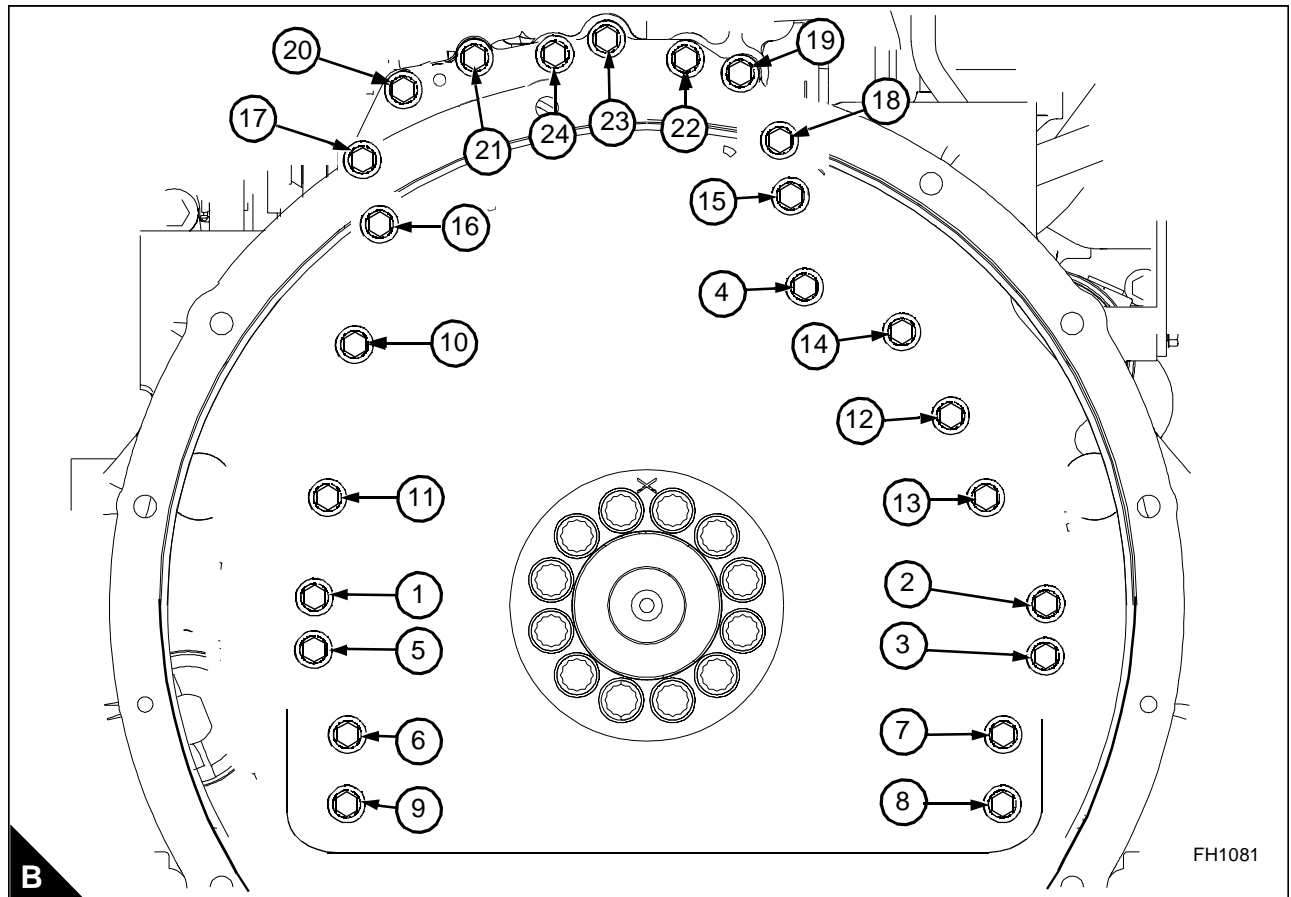
**Caution:** The flywheel housing must be installed in 10 minutes of applying the liquid gasket.

- 4 Use suitable lift equipment in order to fit the flywheel housing to the crankcase. Fit the setscrews which retain the housing but do not tighten at this stage.

*Continued*



5 Tighten the flywheel housing setscrews as follows:



- a. Tighten setscrews (B1) to (C9), in numerical sequence, to a torque of 100 Nm (74 lbf ft) 10 kgf m.
  - b. Tighten setscrews (B10) to (C24), in numerical sequence, to a torque of 40 Nm (30 lbf ft) 4 kgf m.
  - c. Tighten setscrews (B1) to (C9), in numerical sequence, to a torque of 135 Nm (100 lbf ft) 13,7 kgf m.
  - d. Tighten setscrews (B10) to (C24), in numerical sequence, to a torque of 55 Nm (40 lbf ft) 5,6 kgf m.
- 6 Fit the sump, see Operation 10-5.
  - 7 Fit the starter motor, see Operation 14-1.
  - 8 Fit a new crankshaft rear seal and wear sleeve, see Operation 5-3.
  - 9 Fit the flywheel, see Operation 13-1.

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## Electrical equipment

### General information

**Warning!** Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

This section includes the components which form part of the battery charging circuit and the engine starter circuit: the alternator and starter motor. Also engine wiring harness, sensors and the electronic control module. If more information is required, refer to the Diagnostic manual TSD 3453.

A brush-type alternator is fitted at the front of the engine. The alternator unit is driven by a single belt from the fan pulley. The output, 24 volts/70 amps, is controlled by an integral regulator.

The 24 volt starter motor is mounted on the flywheel housing and, when operated, rotates the engine flywheel at a speed that is fast enough to start the engine. When the engine start button is operated, a solenoid, mounted on the starter motor, engages the starter pinion with the ring gear of the flywheel. The circuit which operates the starter motor is completed when the pinion is fully engaged. When the circuit between the battery and the starter motor is complete, the pinion will rotate the engine flywheel. A clutch provides protection for the starter motor so that the engine cannot turn the starter motor too fast. When the start button is released, the pinion is withdrawn from the ring gear.

**Starter motor****To remove and to fit****Operation 14-1****To remove**

**Note:** To assist with the assembly operation, identify and mark the positions of all connections before it is remove.

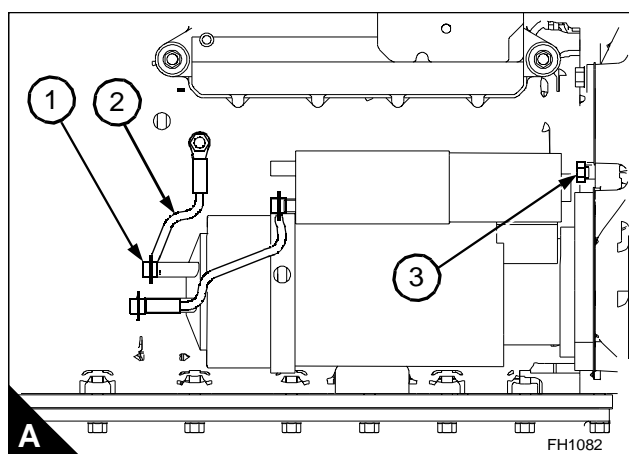
- 1 Disconnect the batteries before any service or repair is carried out.
- 2 Disconnect the earth (A2) and the power connection to the starter motor.

**Note:** Use suitable lift equipment in order to remove and fit the starter motor. The weight of the starter motor is 32 kg (70 lb).

- 3 Remove the three setscrews (A3) and remove the starter motor.

**To fit**

- 1 Align the starter motor to the flywheel housing. Fit the three setscrews (A3) and tighten securely.
- 2 Connect the electrical connection to the starter motor. Tighten the positive connection to 24 Nm (17 lbf ft) 2,4 kgf m and the solenoid connection to 2,5 Nm (1,8 lbf ft) 0,24 kgf m
- 3 Ensure that the earth lead (A2) is connected. Tighten the earth connection to 24 Nm (17 lbf ft) 2,4 kgf m.
- 4 Connect the batteries.



**Alternator**

To remove and to fit

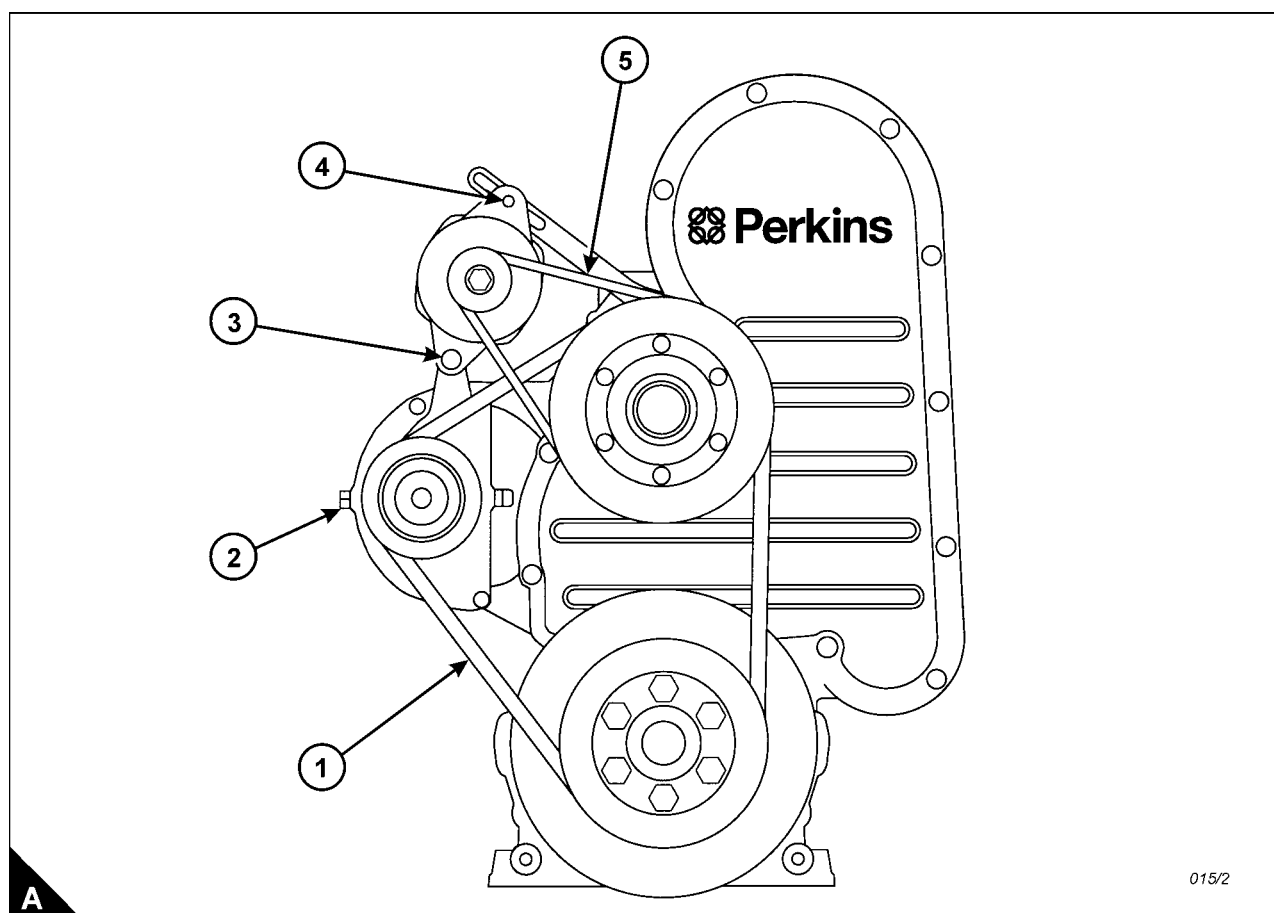
**Operation 14-2****To remove**

**Note:** To assist with the assembly operation, identify and mark the positions of all wiring before it is disconnected.

- 1 Disconnect the batteries before any service work is attempted.
- 2 Remove the access panel in the fan guard.
- 3 Loosen the alternator pivot setscrew (A3), the adjustment link setscrew which is behind the fan pulley and the adjustment setscrew (A4). Move the alternator to release the drive belt and remove the drive belt from the alternator pulley.
- 4 Disconnect the wiring loom from the alternator.
- 5 Remove the setscrews (A3 and A4) and remove the alternator.

**To fit**

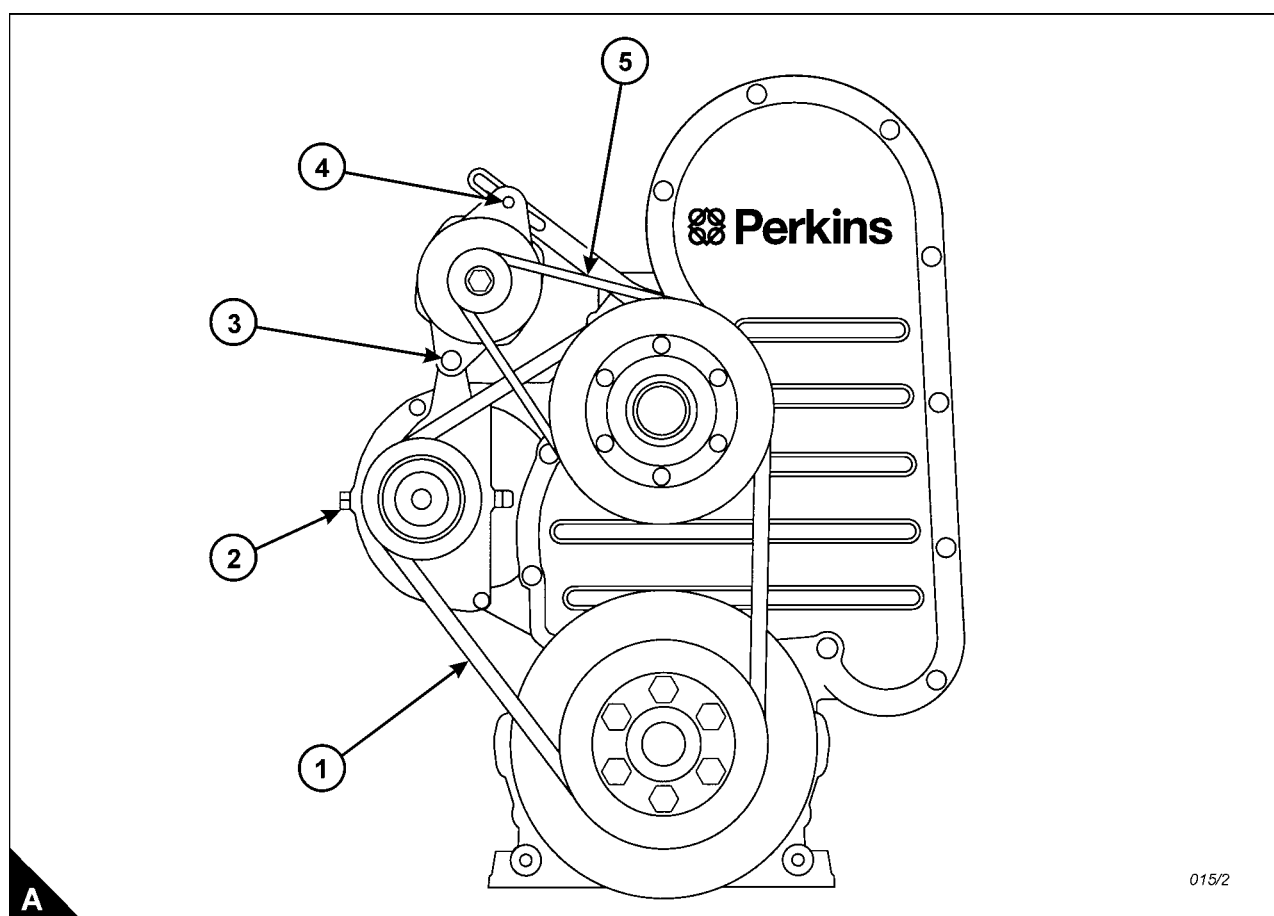
- 1 Fit the alternator and retain with the pivot setscrew (A3) and the adjustment link setscrew (A4). Do not tighten the setscrews at this stage.
- 2 Fit the alternator drive belt over the alternator pulley and set the tension, see Operation 14-3.
- 3 Connect the wiring loom to the alternator.
- 4 Fit the access panel to the fan guard.
- 5 Connect the batteries.



## To check and to adjust the tension of the alternator belt

## Operation 14-3

- 1 Remove the access panel in the fan guard and proceed as follows.
- 2 Use a Borroughs belt tension gauge to check the tension at the position shown (A5). It should be 625 N (140 lbf) 63,7 kgf. To adjust the tension, proceed as follows.  
**Caution:** A alternator belt must be adjusted if the tension is 446 N (100lbf) 45 kgf or below.
- 3 Loosen the alternator pivot setscrew (A3), the adjustment link setscrew which is behind the fan pulley and the adjustment setscrew (A4). Move the alternator to obtain the correct belt tension and tighten the setscrews to 70 Nm (51 lbf ft) 7,1 kgf m.
- 4 Fit the access panel to the fan guard and run the engine for 15 minutes. Remove the access panel and check again the tension.
- 5 If a new alternator belt is fitted, set the tension to 625 N (140 lbf) 63,7 kgf. After the engine has been run for 15 minutes, check the tension and adjust it to 625 N (140 lbf) 63,7 kgf.
- 6 When the correct tension is obtained, fit the access panel to the fan guard.



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To renew the alternator belt

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**Operation 14-4**

- 1 Remove the fan, see Operation 12-5.
- 2 Loosen the adjustment setscrews to release the tension on the alternator belt and remove the old belt. Check that the pulley grooves are clean and fit a new belt.
- 3 Fit the fan, see Operation 12-5.
- 4 Adjust the alternator belt to the correct tension, see Operation 14-3.

**Electronic control module**

To remove and to fit

**Operation 14-5****To remove**

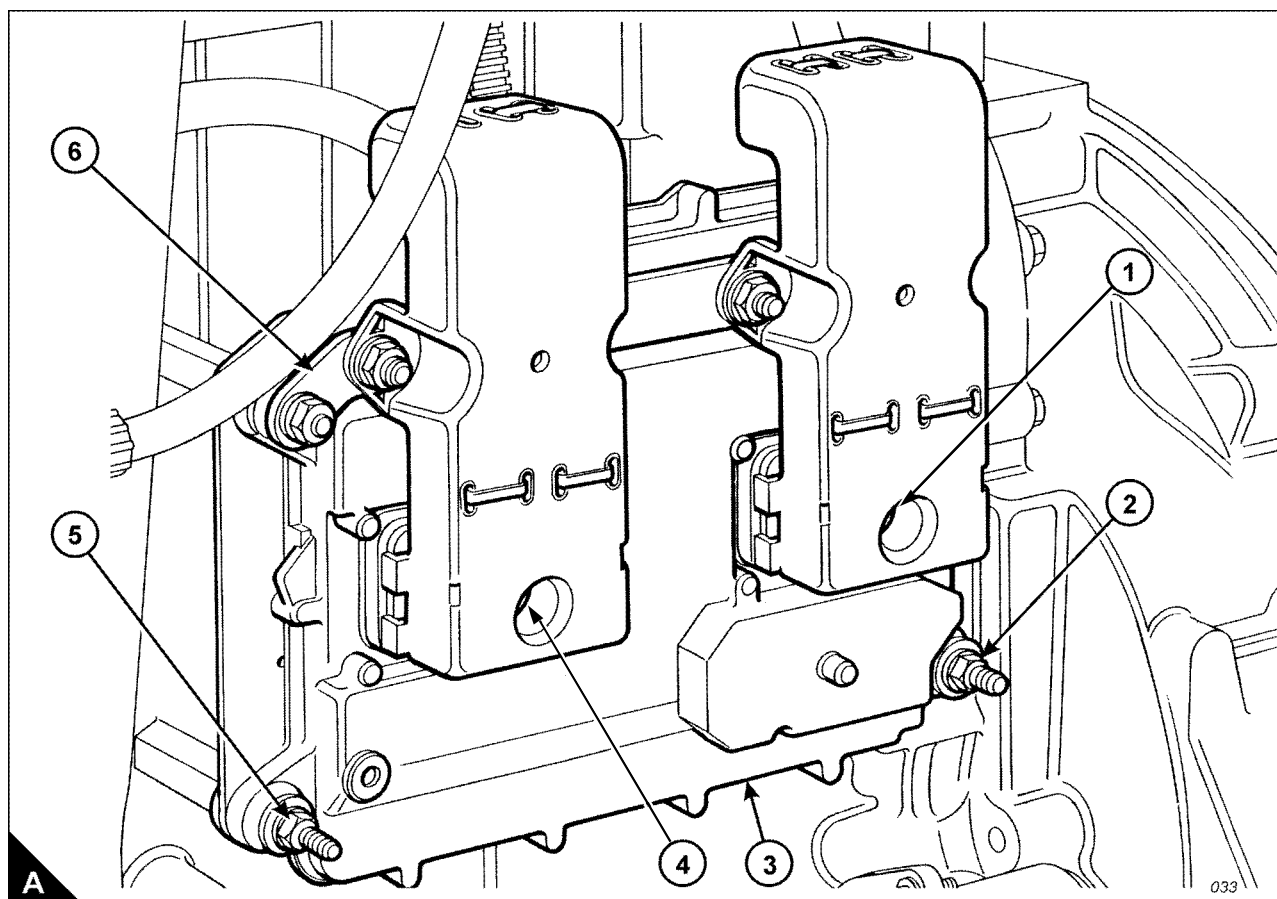
- 1 Switch off the engine and disconnect the electrical power supply.
- 2 Loosen fully the Allen screws from the (A1) and (A2) connectors.
- 3 Remove the two nuts which retain the bar (A6) and the control module (A3), release the ground strap and withdraw the bar and connectors from the control module.
- 4 Support the control module, remove the two remaining nuts (A2 and A5) and remove the electronic control module from the engine.

**To fit**

- 1 Fit the electronic control module. Retain with four nuts, ensure that the ground strap is fitted correctly.

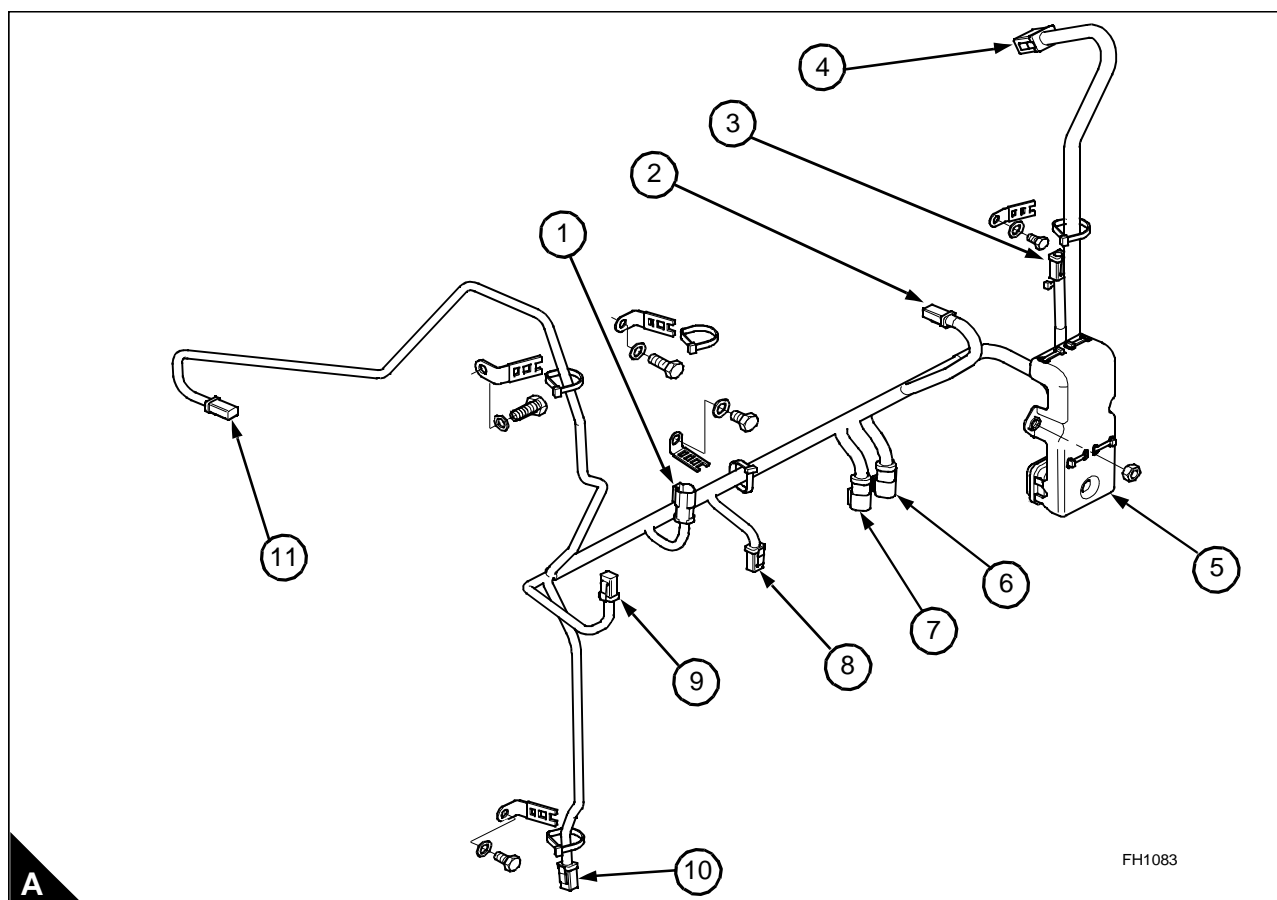
**Note:** To avoid damage to the components, use the Allen screws to pull the connectors (A1 and A4) and control module (A3) together. Ensure that the connectors are aligned correctly and are fitted to the correct positions before the Allen screws are tightened.

- 2 Fit the connectors and tighten the allen screws (A1 and A4). Tighten the allen screws to a torque of 3 Nm (2.2 lbf ft) 0,3 kgf m. Do NOT over tighten the screws.
- 3 Connect the electrical power supply.





## Wiring harness



Wiring harness connections			
(A1)	Inlet manifold pressure sensor connection	(A7)	Atmospheric pressure sensor connection
(A2)	Inlet manifold air temperature connection	(A8)	Fuel temperature sensor connection
(A3)	ECM calibration connection	(A9)	Camshaft speed position sensor connection
(A4)	Electronic unit injection connection	(A10)	Crankshaft speed position sensor connection
(A5)	Engine harness connection	(A11)	coolant temperature sensor connection
(A6)	Oil pressure connection		

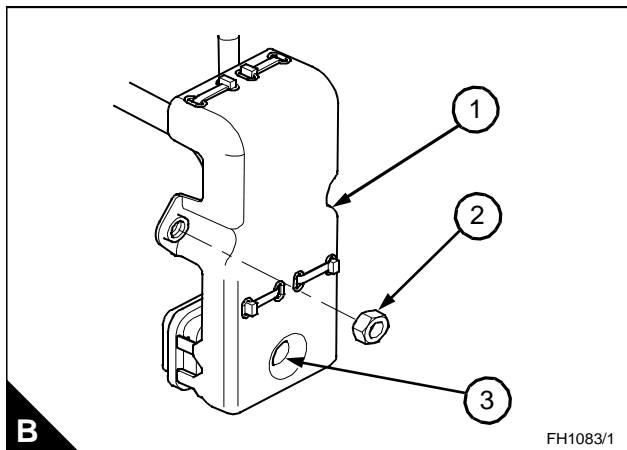
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**To remove**

**Warning!** The electronic control module operates on 110 volts. Ensure that the power supply to the ECM is disconnected before any service or repairs are carried out.

**To remove and fit****Operation 14-6**

- 1 Disconnect the power supply.
- 2 Remove connections (A1) to (A4).



- 3 Remove the nuts (B2) and loosen fully the Allen screw (B3).
- 4 Remove the connector (B1) from the electronic control module.
- 5 Remove connections (A6) to (A11).
- 6 Remove the five setscrews that secure the wiring harness and remove the wiring harness.

**To fit**

- 1 Align the connector (B1) to the ECM.
- 2 Use the Allen screw (B3) in order to pull the connector into the ECM. Torque the Allen screw (B3) to 3 Nm (2.2 lbf ft) 0,3 kgf m. Tighten the nuts (B2) securely.
- 3 Fit the other wiring harness connectors in the reverse order.
- 4 Fit the five setscrews that secure the wiring harness. Tighten the screws securely.

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**Inner wiring harness of the rocker cover**

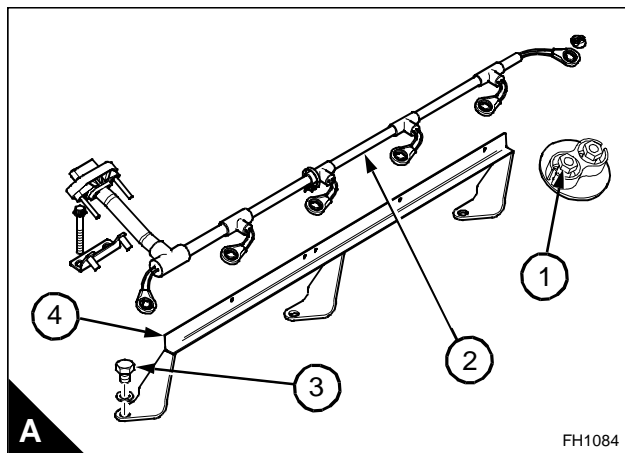
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**To remove****Operation 14-7**

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**Warning!** The electrical circuit for the fuel injector units operates on 110 volts. Do not work on the fuel injector units unless the power supply to the ECM has been disconnected.

- 1 Ensure that the power supply is disconnected.
- 2 Remove the rocker cover, see Operation 3-1.
- 3 Remove the nuts (A1) from each fuel injector unit. If necessary remove plastic clips that hold the inner wiring harness to the support bracket.
- 4 Remove the inner wiring harness (A2) from the engine.
- 5 If required remove the setscrews (A3) and remove the support bracket (A4).

**To fit****Operation 14-8**

---

- 1 If removed fit the support bracket (A4) and the setscrews (A3). Tighten the setscrews securely.
- 2 Fit the nuts (A1) to each of the fuel injector units and tighten to 2,5 Nm (22 lbf in) 0,25 kgf m.
- 3 If removed fit new plastic clips in order to secure the inner wiring harness to the support bracket.
- 4 Fit the rocker cover, see Operation 3-2.

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**Pressure sensor**

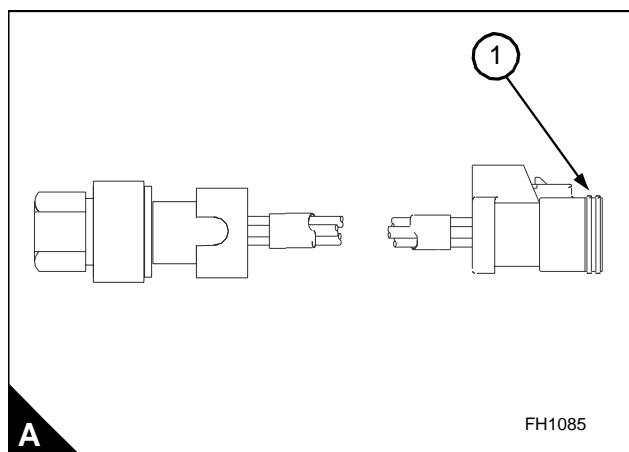
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**To remove****Operation 14-9**

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**Caution:** Do not use power tools in order to remove or fit the sensor.

- 1 Disconnect the electrical connection to the sensor (A1).
- 2 Remove the sensor from the engine. Check the 'O' ring on the sensor. Renew if necessary.



- 3 With the sensor removed ensure that dirt can not enter the engine.

---

**To fit****Operation 14-10**

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- 1 Ensure that the threads of the sensor are clean and dry.
- 2 Fit the sensor into the engine and tighten to 10 Nm (7 lbf ft) 1kgf m.
- 3 Connect the electrical connection to the sensor.

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**Temperature sensor**

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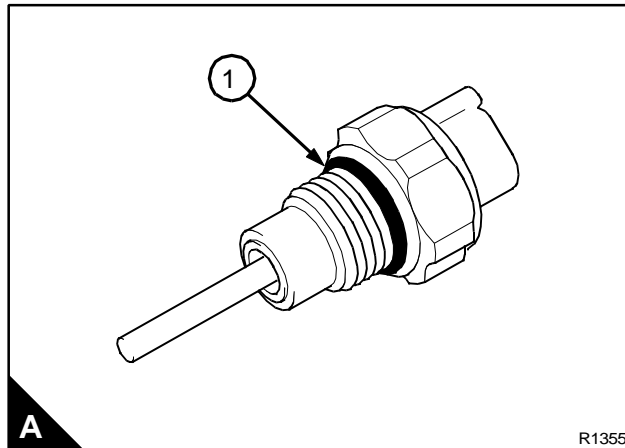
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**To remove****Operation 14-11**

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**Caution:** Do not use power tools in order to remove or fit the sensor.

- 1 Disconnect the electrical connection to the sensor.
- 2 Remove the sensor from the engine. Check the 'O' ring (A1) on the sensor. Renew if necessary.



- 3 With the sensor removed ensure that dirt can not enter the engine.

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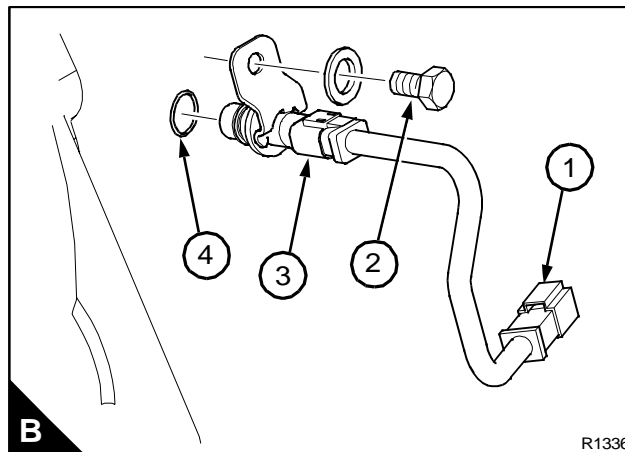
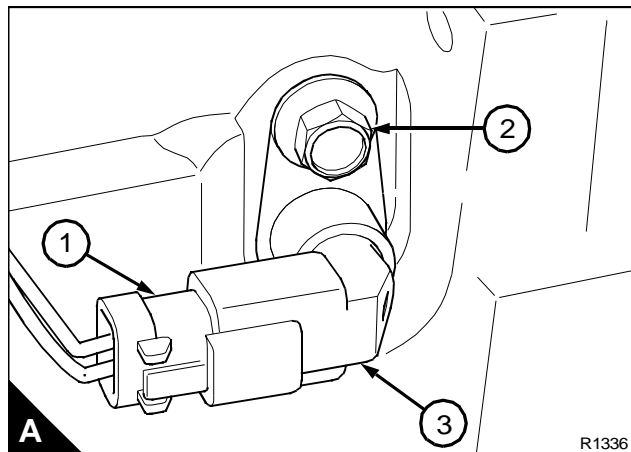
**To fit****Operation 14-12**

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- 1 Ensure that the threads of the sensor are clean and dry.
- 2 Fit the sensor into the engine and tighten to 20 Nm (14 lbf ft) 2 kgf m.
- 3 Connect the electrical connection to the sensor.

**Camshaft and crankshaft speed position sensor****To remove****Operation 14-13**

- 1 Disconnect the electrical connection (A1) and (B1) to the sensor.
- 2 Remove the setscrews (A2) and (B2).
- 3 Remove the camshaft speed sensor (A3) and the crankshaft speed sensor (B3).
- 4 Ensure that dirt can not enter the engine.

**To fit****Operation 14-14**

- 1 Check the 'O' ring (B4) on both sensors, renew if necessary.
- 2 Fit the camshaft speed sensor (A3) and the crankshaft speed sensor (B3).
- 3 Fit the setscrews (A2) (B2) and tighten to 20 Nm (14 lbf ft) 2 kgf m.
- 4 Connect the electrical connection (A1) and (B1) to the sensor.

# 15

## Auxiliary equipment

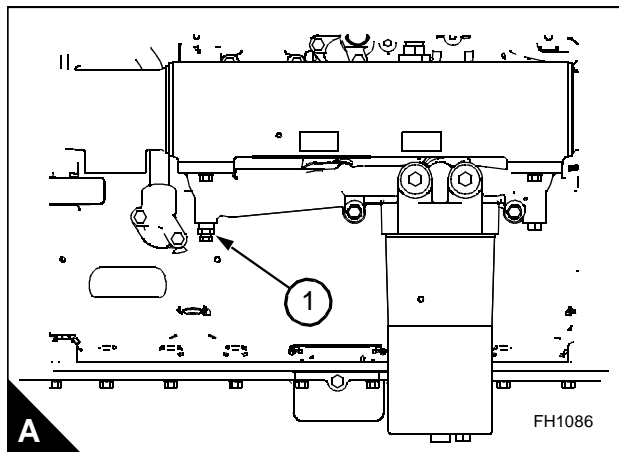
### General information

Some engines are fitted with an oil sample valve. The valve enables a small quantity of oil to be drained. The oil can then be analysed. Details about further auxiliary equipment are not available at the time of print.

### Oil sample valve

**Warning!** The 'O' ring fitted to the oil sample valve contains 'VITON', see the safety precautions for "Viton seals" on page 4.

1 The oil sample valve (A1) is tightened to 24 Nm (17 lbf ft) 2,4 kgf m. Ensure that the torque is applied to that part of the sample valve which is in contact with the oil filter head.



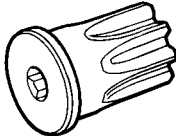
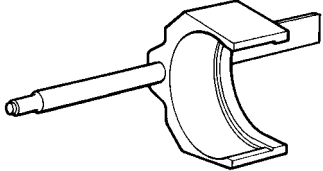
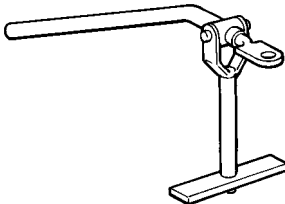
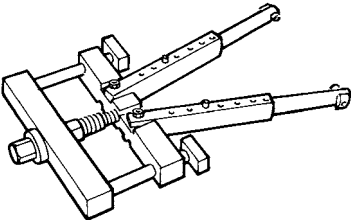
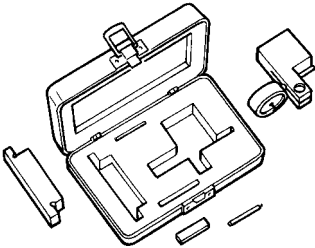
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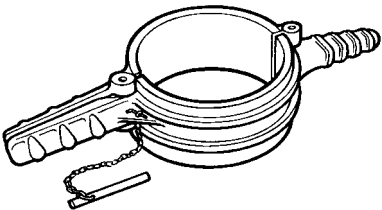
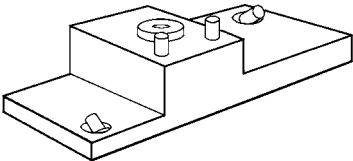
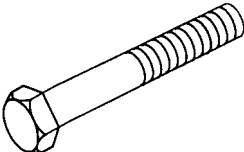


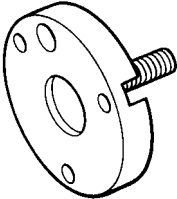


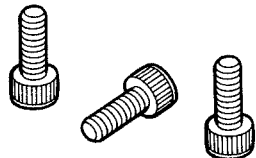
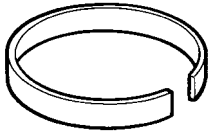
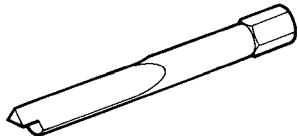
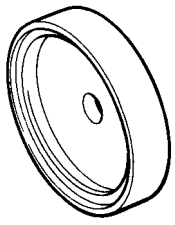
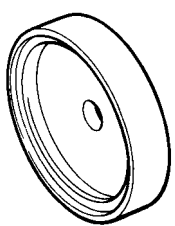
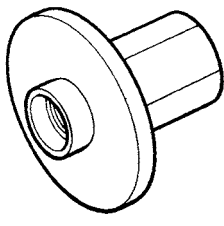
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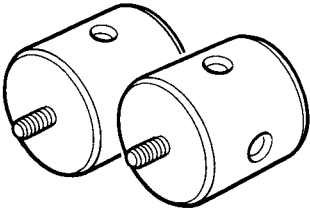
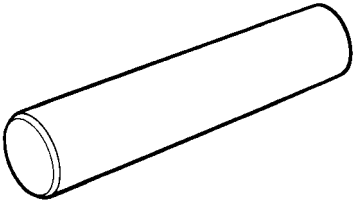
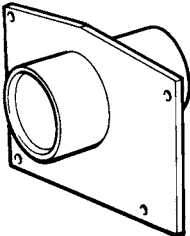
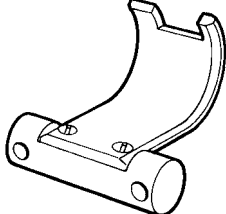
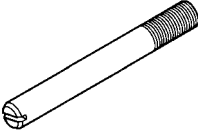
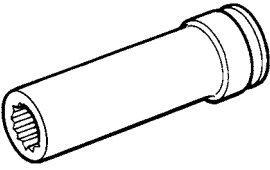
## Special tools

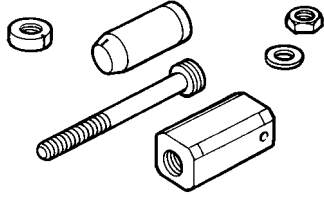
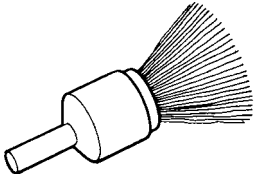

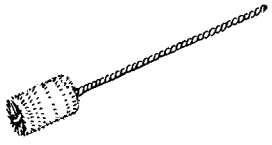
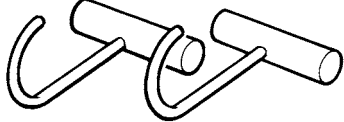
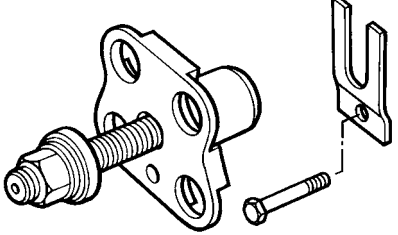
### List of special tools

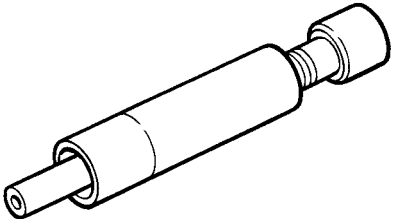
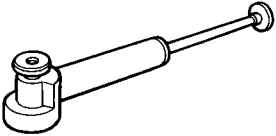
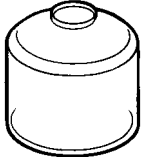
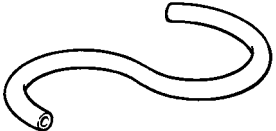
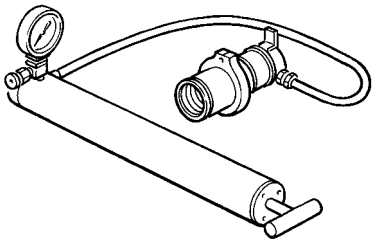
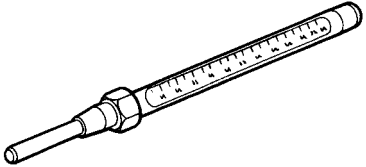
Tool number	Description	Illustration
CH11148	Engine turning tool	
CH11149	Setting gauge, fuel injector	
GE50000	Installer, cylinder liner	
GE50001	Remover, cylinder liner	
GE50002	Height tool, cylinder liner projection	

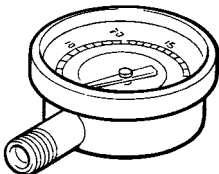
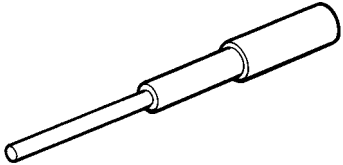
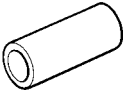
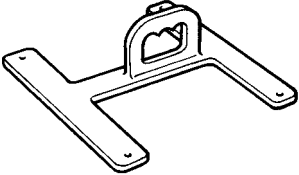
Tool number	Description	Illustration
GE50003	Piston ring compressor	
GE50004	Alignment tool, piston cooling jets	
GE50005	Clamp bolt, cylinder liner (26 required)	
GE50006	Washer (26 required)	
GE50007	Fibre washer (26 required)	
GE50008	Locator, crankshaft seal	

Tool number	Description	Illustration
GE50009	Bolt, crankshaft seal installer (use with GE50008)	
GE50010	Distorter protection ring (use with GE50008)	
GE50011	Distorter tool (use with GE50008)	
GE50012	Installer, front crankshaft seal (use with GE50008)	
GE50013	Installer, rear crankshaft seal (use with GE50008)	
GE50014	Nut (use with GE50008)	

Tool number	Description	Illustration
GE50015	Pilot, camshaft guide	
GE50016	Alignment sleeve, camshaft guide	
GE50017	Guide, camshaft	
GE50018	Cradle, camshaft	
GE50019	Guide stud, camshaft gear	
GE50020	Impact socket	

Tool number	Description	Illustration
GE50021	Remover/installer, injector sleeve	
GE50022	Brush, large bore	
GE50023	Brush, small tapered	
GE50024	Brush, small bore	
GE50025	Lifting hook, camshaft	
GE50026	Compressor, valve spring	

Tool number	Description	Illustration
GE50027	Installer, valve guide seal	
GE50028	Vacuum pump	
GE50029	Vacuum pump bottle	
GE50030	Vacuum pump tube	
GE50031	Pressurising pump, coolant system	
GE50032	Thermometer, coolant temperature	

Tool number	Description	Illustration
GE50033	Pressure gauge	
GE50043	Remover/installer, valve guide	
GE50044	Sleeve, valve guide	
VP12712	Lift bracket, cylinder head	

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